THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

November and December Meetings

AT Boston the Automotive Transportation and Service Meeting will be held, with the Copley-Plaza Hotel as headquarters, on Nov. 16, 17 and 18.

The Tractor Meeting will be held in cooperation with the American Society of Agricultural Engineers at the Hotel Sherman in Chicago, Dec. 1 to 3.

Watch THE JOURNAL and *Meetings Bulletins* for additional information concerning these important events.

Production Meeting This Month

CONVEYORS, gear production, inspection, and machine-tools will be discussed at length at the technical sessions of the Production Meeting that will be held at Hotel Sherman in Chicago, Sept. 21 to 23. Three factory inspection visits of unusual interest and a Stag Carnival will be included in the program that is outlined in detail on p. 201 of this issue of THE JOURNAL. This important feature of the Society's National Meetings Calendar will be truly of production men, by production men and for production men.

Sections Open Season

AT least three of our Sections have scheduled opening events for the month of September. On the evening of Sept. 9, the Indiana Section will hear H. L. Horning speak on the Trend of Engine and Vehicle Design. The curtain-raiser for the Metropolitan Section will take the form of an outing and frolic on Sept. 15. Members of the Cleveland Section will make a pilgrimage on Sept. 16 to Canton, where they will inspect the plant of the Timken Roller Bearing Co. and later will enjoy an afternoon of golf and other sports at Congress Lake Country Club.

Other Sections have scheduled their opening features for the month of October, and according to all indications the 13 active organizations of the Society's membership will have an unusually successful year.

Philadelphia Scores Again

OF unusual benefit were all elements of the Aeronautic Meeting that was held in Philadelphia on Sept. 2 and 3. Chairman W. B. Stout and his committee were eminently successful in arranging a program with tremendous appeal to those desiring to keep abreast of the advancements in the fields of aviation and aeronautics. The technical sessions, the banquet, the inspection visit to the Naval Aircraft Factory and the Warner dinner all contributed toward making the meeting a memorable occasion.

Members of the Pennsylvania Section, constituting local committees in charge of various arrangements for the meeting, merit special mention for their very effective cooperation.

The complete illustrated news account of the Aeronautic Meeting begins on p. 191 of this issue of THE JOURNAL.

Public Library Files of Transactions

AS mentioned in the July issue of THE JOURNAL, in connection with the reduction of stock of available Parts of the TRANSACTIONS for the years 1911 to 1920, the files of the libraries of various Universities and schools that give automotive engineering courses or courses closely related thereto are being completed so far as the Society's stock will permit.

Shipments of volumes of the TRANSACTIONS, as well as of issues of THE JOURNAL for past years, have been made to the following institutions:

Buffalo Public Library, Buffalo
Colorado School of Mines, Golden, Colo.
Harvard University, Cambridge, Mass.
Kansas State Agricultural College, Manhattan, Kan.
Library of Congress, City of Washington
Massachusetts Institute of Technology, Cambridge A, Mass.
New York Public Library, New York City
Northwestern University, Evanston, Ill.
Ohio State University, Columbus, Ohio
Public Library of the City of Boston
Queen's University, Kingston, Canada
Rutgers University Library, New Brunswick, N. J.
Stanford University Libraries, Palo Alto, Cal.
Swarthmore College, Swarthmore, Pa.
Union College, Schenectady, N. Y.
University of California, Berkeley, Cal.
University of Detroit, Detroit
University of Kansas, Lawrence, Kan.
University of Maine, Orono, Maine
University of Michigan, Ann Arbor, Mich.
University of Minnesota, Minneapolis
University of Pittsburgh, Pittsburgh

University of Utah Library, Salt Lake City, Utah.
University of Virginia, University, Va.
University of Wisconsin, Madison, Wis.
West Virginia University, Morgantown, W. Va.
Yale University, New Haven, Conn.

Part I, 1925 Transactions

WORK on the TRANSACTIONS for the first half of 1925 is now actively under way at the printer's. This volume, which, it is expected, will be available about Oct. 15, will consist of approximately 570 pp. and will contain papers presented at the 1925 Annual, Tractor and Service Meetings of the Society, others presented at the Section Meetings and contributed articles that were published in THE JOURNAL from January to June, 1925, inclusive, or 27 articles in all. Since volumes of the TRANSACTIONS are now sent only to members ordering them at the nominal price of $2 a part, members should place their orders by Oct. 1 to be absolutely sure of receiving a copy. A TRANSACTIONS order-blank was mailed in connection with the Aug. 1 issue of the *Meetings Bulletin*. For the convenience of the members who have not already placed orders for this part of the TRANSACTIONS an order blank will be found in the advertising section on p. 112.

Engineering Education

AT a meeting of the Society for the Promotion of Engineering Education, held at the State University of Iowa last June, W. E. Wickenden, director of investigation of that Society, presented a masterly paper on the function and scope of the engineering college, the problems crying for solution in connection with engineering education and the philosophy of the teaching and practice of engineering. This paper was in the form of a preliminary report to the Board of Investigation and Coordination and to the Society with which Mr. Wickenden is associated. The need for non-collegiate technical institutes is outlined, the characteristic techniques of engineering education are discussed in a very interesting and informative manner and the personal adjustments in college life of both students and teachers are treated in an illuminating way. All who are interested in engineering education should study this report. Copies of it may be secured for a nominal sum from the office of the director of investigation, Society for the Promotion of Engineering Education, 29 West Thirty-ninth Street, New York City.

Prof. Charles F. Scott, of Yale University, is the chairman of the Board of Investigation and Coordination. It is expected that the next formal step in this investigational work will be taken at a meeting in November that will be attended by executives and teachers associated with engineering colleges and schools. Excerpts from Mr. Wickenden's report and related documents will appear in THE JOURNAL from time to time.

International Standards

FOLLOWING the activities of the American Engineering Standards Committee in recent years, the advisability of organizing a special body to supervise or participate in the formulating of engineering standards for adoption in various countries has been discussed. In the view of many it is desirable that an international committee on engineering standards be established. International conferences on engineering subjects have, of course, been held from time to time. The International Electrotechnical Commission was organized in 1906 and since that time has been doing work in the electrotechnical and related fields that is very similar if not identical with that of the general engineering nature proposed recently. The American Institute of Electrical Engineers, through its Board of Directors, has expressed the view that, for accomplishing what has been proposed in a general way, the Commission mentioned be expanded and modified to include representation from other engineering bodies, thus accomplishing the purpose in mind without the creation of an additional organized body. In any event the matter of expanding an existing organization or of setting up a new one should receive very careful consideration from the point of view of the affiliating of American interests and the consequent effects of this. A conference of interested members of the Society will be held at its headquarters in New York City at 1:30 p. m., daylight saving time, on Wednesday, Sept. 8. Members of the Society who care to express opinion on the matter will be welcome at this meeting.

Some objection has been made to the provision in a proposed constitution for a new organization that it is exactly like Article X of the League of Nations. One member asks

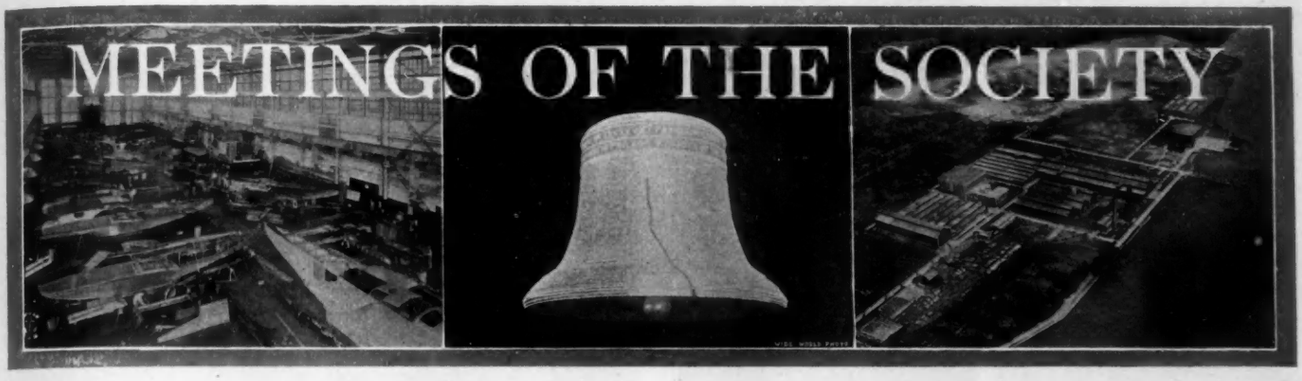
> I wonder whom you are going to pick as the man to do the fighting in connection with what is the proper standard for an American article used in Europe.

A Provisional Committee of Seven has been organized and will consider related matters involved in this whole subject at a meeting to be held in London, England, on Sept. 21.

PHILOSOPHY, SCIENCE AND ECONOMICS

SCIENCE has gained, and rightly gained, preponderant prestige as a method of ascertaining truth, and all investigators are anxious to think and have it believed that their work conforms to scientific method. Philosophy, which properly is the love of and search for truth, is not as alien to science as some may be inclined to think. The theories evolved by philosophy are necessarily, from the nature of its method, tentative, but none the less exploratory. They cannot, however, approach positivism until they are confirmed by science. Indeed, philosophy must wait upon science. But such theories are practically always necessary to afford science a point of departure. In other words, science begins in philosophy.

A fair criticism of all philosophy—and this not only includes cosmic speculation but ethics and most of the theory of human relations—is that, unchecked and uncorrelated, it tends to become unrealizable idealism. Science, on the other hand, is pure realism. And it concerns itself with nothing that cannot be realized. It further recognizes that this realization can only occur through the operation of natural laws that are constant and immutable, something that human sanction or opposition cannot influence. And it only deduces positive theory from such laws. It does not reject tentative theories or hypotheses. But these do not attain scientific rating by affirmation or reiteration, from whatever authority they may emanate. To gain acceptance as scientific truth they must become clearly demonstrable through positive data. And science has long since recognized that positive data can rest only upon a physical basis. Even when deduction and theory are accorded a place in the body of scientific truth they still remain open to revision. The study of economics, if it aspires to unassailable scientific standing, must abide by these criteria.—C. G. Campbell in *Common Wealth*.



THE AERONAUTIC MEETING

Technical Sessions, Factory Inspection and Banquet Enjoyed by Many

Many meetings in the Society's history have registered a larger attendance than that held at the Bellevue-Stratford Hotel in Philadelphia, Sept. 2 and 3, but rarely have the various features of a meeting been so well received by those in attendance. The addresses at the three technical sessions were noteworthy for their wealth of valuable information and technical data. The inspection visit to the Naval Aircraft Factory registered a distinct hit by its very practical nature and because of its skillful handling. All had an opportunity to witness the most interesting activities that are in progress at this progressive plant.

Affording an excellent function for pleasant sociability, the Aeronautic Banquet impressed the members and guests as a brilliant feature of the 2 days of aeronautic activity. No more splendid array of distinguished speakers could be imagined than that including Senator Hiram Bingham, F. Trubee Davison, assistant secretary of war in charge of aviation; Hon. Edward P. Warner, assistant secretary of the navy in charge of aviation; and Hon. William P. MacCracken, Jr., assistant secretary of commerce, in charge of aviation. Grover C. Loening, of the Loening Aeronautical Engineering Corporation, presided as toastmaster in his usually fascinating style. Novelty entertainment features were introduced by the Pennsylvania Section, the members of which were unusually helpful in the conduct of the various activities in connection with the entire meeting.

Friends and admirers of Hon. Edward P. Warner, assistant secretary of the navy, enjoyed an opportunity to honor their fellow-member in the Society through the medium of a complimentary dinner that was held at the Penn Athletic Club on the closing evening of the Aeronautic Meeting. Robert E. Wilson, of the Standard Oil Co. of Indiana, presided very effectively. A. K. Brumbaugh, of the Autocar Co., as Neptune, christened the new Assistant Secretary, and on behalf of Society members launched the good ship Edward P. Warner into the uncharted spaces of naval aeronautics. A beautifully engrossed memento containing the signatures of those in attendance at the Dinner was presented to Secretary Warner, who delivered a very fitting short address.

An illustrated news account of the many interesting events in Philadelphia follows.

AIR-COOLED ENGINE DEVELOPMENT

Cooperation by Navy and Engine Builders Results in Superior Radial Type

Advocates of the air-cooled engine are now prepared to take the offensive in the debate as to the relative merits of this type and the water-cooled engine for aeronautic work, at least so far as moderate powers are concerned. This was made evident in the highly interesting exposition of the development work that has been done on the radial-type air-cooled engine and the results obtained with the latest models, as presented at the opening session of the Aeronautic Meeting on the morning of Sept. 2.

The reversal of position from defense to offense is due to close cooperation of the Bureau of Aeronautics of the Navy Department with the aircraft-engine industry in the last 5 years, which has resulted in making available the Wright Whirlwind and the Pratt & Whitney Wasp and Hornet nine-cylinder engines that give better performance than water-cooled engines of corresponding weight, cooling-system included. Proponents of the air-cooled type at the engine session were led by Commander E. E. Wilson, head of the engine division of the Bureau; George J. Mead, engineer of the

FOUR REASONS FOR THE SUCCESS OF THE AERONAUTIC MEETING

From Left to Right, They Are Paul Henderson, G. L. Martin, J. E. Whitbeck, and E. W. Templin. The First Three Are Members of the Aeronautic Meeting Committee; the Fourth Is the General Chairman of the Pennsylvania Section Committees That Cooperated with Aeronautic Meeting Committee

C. Fayette Taylor

C. L. Lawrance

THEY, AMONG OTHERS, DISCUSSED THE AIR-COOLED ENGINE PAPERS

Pratt & Whitney Aircraft Co.; and E. T. Jones, engineer of the Wright Aeronautical Corporation, who presented the three papers.

Animated discussion that followed disclosed other advocates in Charles M. Manly, whose models of air-cooled engines built 20 years ago and now exhibited at the Smithsonian Institution in the City of Washington embody all of the fundamental principles employed in the latest engines, W. B. Stout, Charles L. Lawrance, and H. Chaminez.

In brief introductory remarks opening the meeting, Mr. Stout, chairman of the Aeronautic Meeting Committee, said that for 20 or 25 years the industry has been a struggling one, living on faith, hope and charity, and this year for the first time looks the world in the face as an industry with a place in the scheme of the Government and a program ahead for every branch of endeavor. Arthur Nutt then took charge of the session as chairman and introduced Commander Wilson.

NAVY REQUIREMENTS AND POLICY

Commander Wilson sketched the airplane requirements of the Navy, outlined the policy of the Bureau of Aeronautics, reviewed the considerations that led the Bureau to concentrate on the air-cooled type, and told of the success that has attended these efforts. His paper is printed elsewhere in this issue of THE JOURNAL.

MEAD DESCRIBES WASP AND HORNET

Members in attendance were greatly interested in a full-size Pratt & Whitney Wasp radial engine and its crankcase that were displayed on a stand and table in the room. The crankcase is claimed to be the largest aluminum-alloy forging ever made in this Country. Design features of the engine were illustrated with 14 lantern slides and described by Mr. Mead. To meet both military and commercial needs, he said, his company undertook the development of a 400-hp. direct-drive radial engine and a 500-hp. model for either direct or geared drive. The design of the Wasp was started Aug. 1, 1925, and the first engine was running in less than 5 months. Within 1 year one engine has had 300 hr. of running and three engines have been flight-tested in as many different airplanes. The design of the Hornet, of identical design but larger, was started last winter and this engine was ready to run early last June.

Especially notable features of the engines are the unit accessory-assembly, which is bolted to the back of the crankcase and is interchangeable on the two models; a short two-piece crankshaft of large diameter and counterweighted; and one-piece connecting-rods without split big-ends. The accessory unit includes two magnetos, a double carbureter, a starter, a fuel-pump, oil-pump, oil strainer, a tachometer, and the necessary gears for 10 different accessory drives, including that for a supercharger impeller. The assembly can be left in its mounting in the fuselage when the cylinders and crankcase that constitute the power element of the engine are dismantled for overhauling or replacement.

Supplementing Commander Wilson's general description, E. T. Jones presented nine lantern slides showing the Wright Whirlwind engines, the cylinder construction of the several models from the J-1 to the J-5 and performance curves of the models. He told of the evolution of the cylinder design and of three 50-hr. tests given the latest model during the present summer. His paper appears in full elsewhere in this issue.

SUPERIORITY OF AIR-COOLING QUESTIONED

In the discussion Chairman Nutt observed that the water-cooled engine is by no means dead, that each type has its place in service and that two arguments made against the air-cooled type are the inability to run them at high speed, as when making a dive, and the cumbersome exhaust-manifolds, which weigh considerable. The latter problem has been solved fairly well, he said, by the Curtiss-Kimball taper-type muffler used on the Wasp.

Mr. Mead questioned the need for very high engine-speed in diving and said the diving speed was more a matter of airplane weight than of engine speed. Charles L. Lawrance said that with the one-piece connecting-rod he doubted if there would be any more trouble in running at high speed than with the water-cooled type. C. F. Taylor remarked that the cooling area is definitely limited by the available surface of the cylinders, whereas in the water-cooled engine the cooling area can be increased almost indefinitely by increasing the size of the radiator. He referred to the automobile water-cooled racing-engines and said that if the water-cooled aviation engine is to survive it must be by a drastic increase in speed.

During the World War engines were run at much higher speeds than they were designed for, according to W. H.

E. T. Jones

G. J. Mead

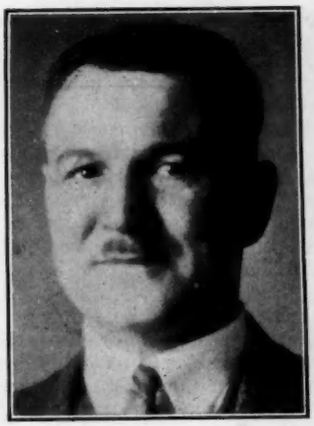
Commander E. E. Wilson, U. S. N.

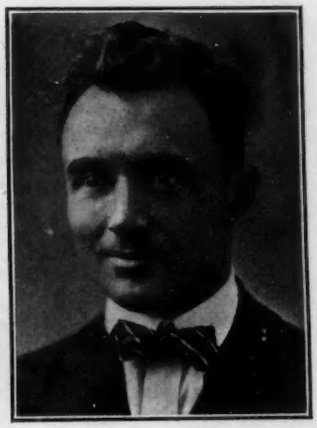
Arthur Nutt

THE AUTHORS OF THE THREE PAPERS PRESENTED AT THE ENGINE SESSION AND THE CHAIRMAN

Lieut-Com. C. E. Rosendahl

Dr. Adolf Rohrbach


Louis G. Meister


Ralph H. Upson

AUTHORS OF THE PAPERS PRESENTED AT THE GENERAL SESSION AND A DISCUSSER

Barling, who told of the practice of trimming down the propellers until the bursting speed of an engine was determined, then running other engines of the same model at 200 r.p.m. less than their destruction speed. The relation of engine speed to airplane performance is closely involved with propeller size and speed, pointed out Mr. Stout.

How Lower Cost Will Come

A plea for reduction in cost of engine materials and accessories for the benefit of commercial engine-builders and users was voiced by R. W. A. Brewer, who said that such users could not pay $5,000 or more for engines. Concluding the discussion, Commander Wilson explained that the fundamentals of cost reduction were the basic reasons for the Bureau of Aeronautics undertaking the development of the radial engine of 200 hp.; that dependability, durability or ease of maintenance cannot be sacrificed to cost in a field in which hazards measure the whole problem; and that as soon as the Air Service has used up its Hispano and Liberty engines and commercial requirements have advanced sufficiently, the cost will come down if all interests concentrate on one type of engine in the 200-hp. field.

As for limitation of the cooling area, he said, the size of the radiator makes no difference; it is a matter of the capacity and surface area of the cylinder. No definite figures are available upon which the Bureau can base a decision regarding crankshaft speed, except on improved performance with reduction gearing, but a series of performance tests has been initiated at Langley Field to obtain such data. The Bureau is convinced, he stated, that the air-cooled engine is doing better than any water-cooled engine, because it can be supercharged to a high degree at sea-level; however, it is not thought that the water-cooled engine is doomed, it is necessary, for example, in the Amphibian, but the direct method of cooling, said Commander Wilson, like the direct method of doing anything, is better than the indirect method.

GENERAL SESSION COVERS WIDE FIELD

All-Metal Airplanes, Types for Individuals and Airship Handling Treated

Possibilities of development seemingly limitless in extent were indicated for the future of aviation by the notable speakers at the general session held on the afternoon of Sept. 2, as, under the able chairmanship of Alexander Klemin, associate professor of aeronautics, New York University, the program was unfolded, the wonderful progress already accomplished was outlined and achievements yet to come were predicted. Three papers were presented and each one was discussed snappily. The interest of the large audience was compelled further by the accompanying illustrations and by the models of airplanes and of aircraft engines on exhibition.

All-Metal Airplane Production

Economical and Rapid Production of All-Metal Airplanes and Seaplanes was the title of the paper by Dr. Adolf Rohrbach, of the Rohrbach Metall-Flugzeugbau, Berlin, Germany. Owing to the unavoidable absence of the author, the paper was presented in abstract form by Charles H. Keel.* It dealt with the structural practices of the company represented by the author and was illuminating and in some respects startling in its content, particularly with regard to wing loading and characteristics of design. The importance of the time and the cost required for construction was emphasized. It was said that knowledge applying to structural matters is now so exact that calculations are only from 3 to 5 per cent of being exact and that actual performance is not much more than 5 per cent from being exact when uncertain factors such as weather conditions are taken into account. The time and the cost of building new types are reduced by constructing workshops that are practically ideal, using many jigs and fixtures, making extremely accurate working drawings, and paying great attention to perfection of organization. The tendency is toward the assembly of built-up units, interchangeable parts and the use of other accepted production methods. The raw material is the best obtainable, no closed tubes or other construction likely to encourage subtle corrosion are used and all parts are made accessible. An effort is made to adopt materials and methods that are in use in other industries, as well as to utilize men whose experience has been in other lines of work. As an instance, ship riveters in Copenhagen readily adapted themselves to the work of riveting the all-metal wings. It was mentioned also that manufacture can be carried on in any country, and that working drawings are made so systematically and exactly that production has been carried on successfully and simultaneously in Copenhagen, in Glasgow and in Japan although no supervising representative of the company was present during the construction. An endeavor is made to secure the highest possible wing loading. Monoplanes are built exclusively. The flying boats built by the company have, on either side of the fuselage and adjacent to it, a float or pontoon; these two floats greatly increase the lifting power on take-off. The twin powerplants are mounted on elevated structures above the fuselage.

In opening the discussion, Assistant Secretary of the Navy E. P. Warner said in part that all-metal construction is of very vital concern in all countries at present, in this Country as well as in Europe, and more particularly the application of metal construction to hull design because somewhat different lines of development in this respect have been followed by a number of different manufacturers in Europe and by naval interests and some private manufacturing companies in the United States. He expressed his conviction that the point made in the paper regarding economy is one

of extreme importance. He remarked further that while for airplanes we can afford to pay a much higher price for a saving of weight and for an increase of efficiency than for any other type of engineering structure, at the same time it is of the utmost value that we try to develop methods of construction, and especially of metal construction, which almost inevitably adds considerably to the cost, at least for small numbers of units. He felt also that it is of the utmost importance to develop methods that will make it possible to standardize sections and to reduce the number of man-hours of labor involved in putting them together. He said that effort to that end is now being exerted in this Country.

W. B. Stout questioned the advisability of "talking cost" at this stage of the art of aviation. He thought the cost of any product is more a matter of quantity than of design and that, as the quantity of production increases, the very production methods themselves force gradual development toward cheaper ways of doing the thing that at first was expensive. Present very expensive all-metal construction will, by such a process, he argued, eventually come to be done for cents in place of the dollars it costs now. He then elaborated upon the fact that a commercial airplane must be able to support itself in the air financially. W. H. Barling, Ralph H. Upson and others also contributed valuable discussion of the paper.

Airplanes for Individual Ownership

Louis G. Meister, of the Buhl-Verville Aircraft Co., Detroit, said in part that the requirements for airplanes for personal use are governed by individual preferences and by geographic location. Airplane performance must be such as to meet these requirements. He advised the adoption of definite factors of safety for the structural parts of commercial airplanes, similar to those demanded in military aviation but modified because commercial-airplane service is less severe. For the smaller types the present training-airplane safety-factors for structural parts will suffice; for the larger types, factors similar to those now used in airplanes of the transport type are suitable. Safety in flying is paramount.

Experienced pilots agree that excess power is the foremost safety feature in an airplane, because a machine that can climb fast can be controlled better and more quickly, requires a shorter run before take-off, is able to climb out of a small field better, and gives the pilot greater leeway for maneuvering in case of engine failure when taking-off. More crashes occur on take-offs than from straight flying or landing, because of failure to reach a sufficient height and gain full control for maneuvering. Other features of his remarks related to enclosed cabins, the use of brakes to facilitate quick stopping, folding wings, and miscellaneous desirable practices regarding design.

After the opening of the discussion, interest centered for a time on whether the pilot should be enclosed in the cabin or whether he should be out in the open and the passengers only enclosed in the cabin, in airplanes so equipped. Varied experiences were related, for and against each method, and the subject is still debatable. Ralph H. Upson remarked on the similarity of the arguments used to those referring to the respective merits of open and of enclosed automobiles. W. H. Barling expressed his reasons for fearing Government control of civil aviation, saying that such control in England had killed all commercial aviation of the type based on individual ownership. Mr. Meister deplored promiscuous flying of low-powered airplanes, saying that no crashes occurred on the Ford tour that were due to the airplanes, and that the only crashes were due to Gypsy pilots who came into the fields at Kansas City, Mo., and at Des Moines, Iowa, flying old so-called "crates." He argued strongly for adequate inspection and control and also enlarged upon the subject of brakes for airplanes, mentioned in his paper.

Methods for Mooring and Handling Rigid Airships

Lieut-Com. C. E. Rosendahl, in command of the Naval Air Station, Lakehurst, N. J., told in his paper how the foregoing methods had been developed and applied, giving many side lights on airship control and operation. Some of the causes of the difficulties experienced were attributed to the scarcity of helium gas, the location of the station, lack of adequate and sufficiently frequent weather forecasts, and insufficient funds provided for development. For example, in one instance, he said that if it were possible to "valve" helium freely, as would be the case if the gas were plentiful and cheap, an airship could fly with much less restriction due to weather conditions than is true at present. In regard to mooring, only one base is properly equipped, and the fact that it is in the path of every transcontinental storm is a serious additional risk. At that, flights foregone in these times of peace, easily could have been made in time of war. He advocated weather maps of the Atlantic Ocean and comprehensive weather-prediction service in general. He described landing an airship from flight, caring for the ship between flights and maneuvering it in and out of its hangar. Mechanical aids to landing are being developed that will, it is expected, enable the reduction of the ground crew by say 100 men. At present, about 250 men are needed. Comparing mooring to a mast on land with mooring to a mast installed on a ship, the former is more difficult because of the currents of air that rise vertically under a high mast on land. Methods of landing an airship on the ground and supporting it in cradles were also discussed.

Mention was made in the discussion of the paper of the difficulties that attend the transition stage between the air and the ground; getting the ship off the ground into the air and from the air down to the ground causes the major troubles. The tubular type of mooring mast was described briefly and its merits stated. Neil MacCoull remarked the effect of engine control on the maneuverability of the airship under discussion; he mentioned the ease with which its engines start when cold and the almost instant response of the engines when suddenly reversed. Ralph H. Upson said that the commercial airship must be capable of flying anywhere in any kind of weather, be safe when using any kind of gas and constructed so that it can be moored permanently out in the open. Hangars should be used for drydock purposes only, such as overhauling. In conclusion, Commander Rosendahl replied to the various questions raised and to the points brought out by the speakers in the audience, describing also the landing of a light or buoyant airship by a novel use of the engines to create suction under the ship.

PUBLIC MUST BECOME AIR WISE

Distinguished Speakers Tell of Progress Already Made and Problems Yet Unsolved

Exceedingly valuable and informative, according to Toastmaster Grover Loening, was the address given by Senator Hiram Bingham, the principal speaker at the Aeronautic Banquet, which took place on the evening of Sept. 2, in the ballroom of the Bellevue-Stratford Hotel, Philadelphia. The audience of nearly 250 Society members and guests, agreeing thoroughly with their genial toastmaster in this summing up of Senator Bingham's brilliant speech, considered the characterization equally applicable to the words of the other speakers who contributed to the success of what was undoubtedly the most enthusiastic Aeronautic Banquet ever held by the Society.

The air of good-fellowship that pervaded the gathering received an added note of gayety from the toy balloons which had been placed at each table by the Pennsylvania Section. These colorful toys were quickly inflated; many of them were tossed around the room, and as time went on, a great many of them experienced a sudden and noisy deflation. At each place, a key ring had been placed before the guests assembled; this too was the gift of the Pennsylvania Section. While dinner was being served, music was dispensed both by a tuneful orchestra and by a melodious and harmonious quartet of male voices.

An innovation was the substitution, for the usual menu card, of a large blue-framed bulletin board that stood in one

corner of the room. The inscription on this board swiftly and silently changed from time to time, first bidding all welcome, next listing those at the speakers' table, then giving the menu, and successively announcing the various parts of the program.

At the speakers' table, in addition to Toastmaster Loening, were seated the following: Senator Hiram Bingham, Dr. George K. Burgess, Godfrey Cabot, Admiral H. I. Cone, Mr. Davis representing Mayor W. Freeland Kendrick, F. Trubee Davison, Lieutenant-Colonel Foulois, Brigadier-Gen. W. E. Gillmore, Wing Commander T. G. Hetherington, Dr. George W. Lewis, W. P. MacCracken, Jr., Frank H. Russell, E. P. Warner, H. F. Wehrle, and Capt. G. C. Westervelt, U. S. N.

One of the interesting features announced by the bulletin board was a novelty by the Pennsylvania Section. During dinner the guests became aware that diminutive airplanes were being wafted around the room. Each airplane stayed in the air for some time, but finally the law of gravity prevailed. When the members caught the tiny paper objects that fell in their vicinity, they noticed that each plane bore a number. A. K. Brumbaugh, chairman of the Reception and Entertainment Committee for the Aeronautic Meeting, drew a series of lucky numbers and announced that each holder of a lucky number would be given a ride, on Friday afternoon, in a Pitcairn airplane.

Toastmaster Grover Loening, after appropriate introductory remarks relative to the part played by the Society in the advancement of aeronautics in this Country, presented the first speaker on the program, Mr. Davis of Philadelphia, who represented Mayor W. Freeland Kendrick. Mr. Davis, expressing regret at Mayor Kendrick's inability to attend, spoke of the interest that Philadelphia holds for visitors from the standpoint of historical association and present development including the Sesquicentennial Celebration. Speaking of transportation as one of the great problems of the future and commenting upon the part that must be played by the Society in solving it, the Mayor's representative extended to the Society a hearty welcome to the City of Philadelphia.

After acknowledging these words of welcome, Mr. Loening pointed out that the role of the engineer is still paramount in aviation because so many developments are yet in the future and considerable research must be done before these developments can be made. Commenting appreciatively on the valuable research work that is being done by the National Advisory Committee for Aeronautics, the oldest Government organization that is concerned with aviation, Mr. Loening called upon Dr. George W. Lewis, of the National Advisory Committee for Aeronautics, to say a few words. Dr. Lewis spoke briefly of the inception, the establishment and the work of the Committee, attributing its success to the fact that it is a cooperative unit. Its policy, he said, restricts its investigations to fundamental principles of aeronautics. Commenting on the importance of this type of investigation and pointing out that a very small proportion of any appropriation for aviation is devoted to research, Dr. Lewis made the plea that the Society continue its support for aeronautical research which he considers the very life-blood of the industry.

Public Should Be Taught the Truth about Aviation

When introducing the next speaker, Toastmaster Loening touched upon the advantages derived by the industry from the presence in the Senate of a man whose activities have familiarized him with the problems of aviation. Mr. Loening outlined briefly the aeronautical experience of the distinguished Senator who was the subject of his remarks, whom he presented as the principal speaker of the evening, Senator Hiram Bingham of Connecticut.

Senator Bingham mentioned with evident pleasure the fact that aviation has never become a party issue but that legislators on both sides of the aisle have tried to do their best for its progress. He stressed the need for teaching the people of the United States the truth about aviation so that they would know what could be done, what could not be done, what should be expected, and how much the necessary developments would cost, so that they would be willing to pay, through appropriations, for the advancement of aviation. This education of the public, he said, must take the direction of fostering among the people an air-minded attitude, so that they will think in terms of the needs, the problems and the possibilities of aviation. Senator Bingham spoke briefly but clearly and interestingly upon some of the problems that will be encountered and pointed out the respective roles of the Government and private enterprises in furthering aeronautical progress.

Aviation, he said, is a proper handmaid for commerce and one of the greatest possible aids to the Army and the Navy. The appointment of the Assistant Secretaries in the War, Navy and Commerce Departments will undoubtedly go a long way toward securing for our Country leadership in the air and the young men who have been appointed have within them the qualities that will assure success, provided they receive the support of the public. This support, Senator Bingham pointed out, will come only if the people develop the air-mindedness that he had already mentioned, and he spoke of the part that should be played by aeronautic engineers in seeing that the public receives the true and proper education to create and foster this attitude toward aviation which, he asserted, may be expensive but is indispensable.

After thanking Senator Bingham for his exceedingly valuable and informative address, Toastmaster Loening with appropriate remarks introduced in turn F. Trubee Davison, assistant secretary of war; Edward P. Warner, assistant secretary of the navy, and W. P. MacCracken, Jr., assistant secretary of commerce.

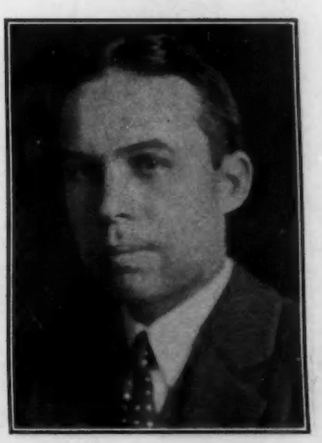
The Army Air Service's Contribution to Aeronautical Progress

Assistant Secretary Davison told briefly about the contribution to aeronautical progress, made by the Air Service

Hon. Hiram Bingham

Hon. F. Trubee Davison

Hon. W. P. MacCracken, Jr.



Grover C. Loening

Three of the Speakers and the Toastmaster at the Aeronautic Banquet

working in cooperation with the industry and with other Government departments. The people, he said, do not seem to realize the extent of the development that has taken place, perhaps because the progress, though rapid, has been gradual rather than radical. Referring to the work at McCook Field, in Dayton, which he regards as of importance not only from a military standpoint but from the standpoint of the development of aeronautics as a whole, he named as some of the principal projects at McCook Field, the following: powerplants, propellers, landing gears, the radio beacon, photography, the supercharger, flying instruments, night-flying equipment, armament, and lighter-than-air equipment.

The speaker then gave a more detailed consideration to two pieces of work that have been carried on at McCook Field, considering them of fundamental importance because they have added an additional safety factor to flying; these two items are the developing and perfecting of parachutes and the discoveries that have practically eliminated fire when airplanes crash.

In conclusion, Mr. Davison spoke of the important part played by members of the Society in national defense, in peace as well as in war, and hoped for a continuance of the spirit of helpful cooperation that exists between the Air Corps and the Society.

Establishment of Understanding Among Research, Design and Operation Branches

Assistant Secretary Warner spoke concisely of the general problems confronting engineers, particularly with reference to the establishment of mutual understanding between those in the designing end of the game and those concerned with operation, as well as between the research man and the designer. Describing a specification as an attempt to express in a reasonably small number of words the average of a large accumulation of experience, he discussed the situation of a designer confronted by a specification, endeavoring to obtain all available knowledge to help him in solving his problem. The role of the engineering society as a vehicle of cooperation between men working in distinct but closely allied fields was given due consideration by the speaker, who spoke of the function of Society meetings in filling in, through direct contact and collective discussion, that twilight zone between the research worker and the practical designer, between the designer and the operator. He expressed the opinion that the greatest service which technical sessions perform is in clearing up the borderland between the different fields of activity and in the stimulation of cooperation and meeting on common ground of all concerned in the theoretical study, the design, the construction, and the use of aircraft. The speaker drew an analogy between the present situation of aircraft and the old days of the automobile industry when the failure of one vehicle was a reflection on all others, and he urged the consequent need for cooperation among all concerned in the development of aircraft.

Safety, Cost and Comfort Three Problems of Civil Aviation

Assistant Secretary MacCracken, after expressing appreciation of the activities of the Society in the field of aeronautics, outlined interestingly some of the problems that are of importance to civilian flying. Safety received his first consideration. It will come, he said, through a reduction in accidents by the improvement of engineering and navigational aids and by the improvement of the design of the aircraft to minimize danger. Another problem that aviation must face, he said, is that of cost, both of the equipment itself and of operation. A third problem to which Mr. MacCracken devoted some attention was that of comfort; aircraft, he said, will conserve people's time and, when air travel can be accomplished with comfort equal to or in excess of that offered by surface transportation mediums, they will be willing to pay a substantial premium.

At the close of the banquet, Toastmaster Loening sounded an optimistic note as he looked toward a superlatively bright future for aviation.

NIGHT FLYING AND SIGNALING METHODS

Storm and Fog Troubles, Airway Lighting and Radio Direction-Finding Described

Twenty-four-hour operation of commercial airways through all seasons presents a plenitude of problems for solution although much apparatus has been developed to aid pilots in keeping on their courses and locating and landing at flying fields despite adverse weather conditions. Such is the impression left by the four speakers at the Air-Transport Session of the Aeronautic Meeting in Philadelphia on the morning of Sept. 3.

Air-Mail Pilot Wesley L. Smith gave an absorbing and excellently delivered account of how he flies the Air Mail route by night from New York City to Cleveland and of the instruments on the airplane that aid him in his hazardous occupation. His address was illustrated with a large map of the course, on which a profile below showed the mountains and valleys that make the section from Allentown to Bellefonte, Pa., so difficult, and a lantern slide of the instrument board of the night mail airplane. This board includes a compass, an altimeter with calibrating dial, a speedometer showing the flying speed in miles per hour, an engine-revolution indicator, a bank indicator having a steel ball that rolls in a curved glass tube filled with alcohol, and a clock in addition to the instruments for operating the engine.

The two greatest obstacles to flying, which also will be the most difficult for commercial operators to overcome, said Mr. Smith, are fog and the formation of ice on the airplane when flying through clouds at certain temperatures. Deep fog completely blankets out everything below it both by

E. L. Clark

O. M. Thornton

D. P. Bachman

A. K. Brumbaugh

A Quartet of Local Talent Who Served in Various Capacities

THE FOUR AUTHORS OF TWO PAPERS DESCRIBING THE LATEST DEVELOPMENTS IN TWO FORMS OF AID FOR THE AIRMAN

H. C. Ritchie and C. T. Ludington, the Civilian Members, Told of What Is Being Done To Light Airways, Airports and Airplanes; While the Two Army Officers, Capt. W. H. Murphy and Lieut. L. M. Wolfe, Demonstrated, with the Aid of a Motion Picture, the Newest Thing in the Way of Radio Direction-Finding Apparatus

day and by night, but it is easier to land through fog on a dark night than in daylight or moonlight, which are reflected upward by mist whereas on a dark night the lights of a landing-field make a glow that can be seen from a fair height. What is needed, however, is a light that will penetrate fog to a great height or distance.

At temperatures of from 10 to 32 deg. fahr. ice collects on the airplane when flying through clouds and will overload the ship in 1 hr. so that it will drop like a stone and will increase the landing speed by between 25 and 30 m.p.h., Mr. Smith said. He never has heard anyone offer a practical solution for overcoming this difficulty and thinks that the suggestion that heat in metal wings may be the answer may not prove true, as in flying through a sleet storm from Cleveland to Bellefonte his navigation instruments became so coated with ice that they could not be read.

Other interesting and instructive facts regarding bad-weather and night flying drawn from Mr. Smith's 10-years' experiences as a pilot will be found in his complete paper as printed in this issue of THE JOURNAL. Commenting upon the address at its conclusion, William B. Stout, who presided as chairman of the session, said that it presented some new light on the question, How long does it take to learn to fly, and also on the matter of essential flying-instruments.

HOW AIRWAYS AND FIELDS ARE LIGHTED

H. C. Ritchie, of the General Electric Co., told of the lighting requirements for airways and landing-fields and described the rotating electric beacons used on the Air Mail and other courses and the flood-lights and boundary lights used at terminal and emergency landing-fields. His paper was illustrated with a score of lantern slides.

A second part of this same subject was dealt with by C. T. Ludington, of the B. B. T. Corporation, a French and American company, who gave a more detailed description of the lighting equipment developed by his own and other companies in recent years from experience gained in equipping marine lighthouses. In a dozen lantern slides he showed the great 1,000,000,000-cp. Dijon light in France near Paris, various types of lamps used for flood-lighting landing-fields, small acetylene flashing airway-markers, the neon-gas light installed on the Chicago-to-Dallas National Air Transport route, and lighting equipment used on airplanes. The two-part paper by Messrs. Ritchie and Ludington also appears in this number of THE JOURNAL.

RADIO DIRECTION-FINDING MADE PLAIN

Enthusiastic reception was given by the audience to a two-reel motion picture that admirably demonstrated the method developed by the Signal Corps radio laboratory at McCook Field, Dayton, Ohio, for direction finding by radio. This film had just been finished and was shown for the first time at the Aeronautic Meeting by Lieut. L. M. Wolfe, who presented a joint paper on the subject by Capt. W. H. Murphy and himself. Another novel animated exhibit was a map of the Eastern section of the Country mounted on an easel and showing flashing electric lights operated automatically. The course from New York City to Chicago showed white lights, while the area to the south showed red lights and that to the north showed green lights. The purpose of the device was to indicate visually how pilots when on the course receive one type of radio signal and when off the course to right or left receive different signals that aid them in getting back on the route.

The first reel of the motion picture showed the receiving set mounted in the fuselage, the observer's helmet, the reel antenna and the way it is grounded to the metal of the airplane, the use of a lead "fish" in connection with the antenna, the ground-station antenna and transmitter, the 75-ft. aerial mast, an electric motor and cams sending the distinctive a (.—) and n (—.) signals in the Morse code which interlock and form the signal t (—) when of equal intensity and at a certain angle to the sending loops, and diagrams of the position of the loops.

The second reel showed the goniometer used with the rotating loops employed for the equisignal system, the automatic key for sending the two letter-signals intermittently, a portable receiver used at the sending station for checking the t zone with the selected course, flying in an airplane through clouds from the City of Washington to Dayton, and diagrams illustrating how a pilot finds his course by flying first to one side then to the other to pick up the different signals.

Wesley L. Smith W. B. Stout

MR. SMITH RELATED HIS EXPERIENCES AS A PILOT ON THE OVERNIGHT AIR MAIL BETWEEN NEW YORK CITY AND CLEVELAND; MR. STOUT, IN ADDITION TO BEING CHAIRMAN OF THE AERONAUTIC MEETING COMMITTEE, ACTED AS CHAIRMAN OF THE AIR-TRANSPORT SESSION

To obtain an adequate comprehension of the radio signal-system as exemplified by this motion-picture film it is necessary to read the paper on the Stationary and Rotating Equisignal Beacon in another part of this issue of THE JOURNAL.

At the end of the address, Lieutenant Wolfe said that developments are going on in the radio field to enable a pilot to bring his airplane down safely through fog, to produce a radio altimeter and a method of determining the boundaries of a landing-field by variation of induction and to perfect a process for transmitting photographs by radio from an airplane to a station on the ground.

Delivery of the several papers consumed the full time of the session, leaving none for discussion, but all of the addresses were so absorbingly interesting that the 2½ hr. had passed with the speed of an airplane and no regrets were expressed when Chairman Stout announced in adjourning the meeting for luncheon and the Naval Aircraft Factory visit in the afternoon that any discussion would have to be written and mailed to THE JOURNAL.

AIRCRAFT FACTORY VISITED

Interesting Factory Inspection Trip Made to League Island Navy Yard

A large representation of those attending the Aeronautic Meeting spent the afternoon of Friday, Sept. 3, in making an inspection trip through the Naval Aircraft Factory. The journey from the hotel to the factory was made in motor-coaches provided through the courtesy of the Philadelphia Rural Transit Co. Among the interesting items that were explained to the visitors by representatives of the Factory were the new PN-10 airplanes that are said to be the latest word in patrol aircraft, and are a development of the PN-9 airplanes which were used in the Pacific flight last year; the Navy Curtiss racing airplane that won the world's speed record in the Schneider Cup Race last year; the Loening Amphibian; a large variety of aircraft engines under test on the dynamometer stands; the experimental laboratory; and countless other intriguing features.

One of the interesting events was the catapulting of an airplane and pilot from a standard shipboard catapult. Another novel feature was the arrival and landing of a commercial airplane carrying passengers from the City of Washington, its interim inspection and tuning-up for the return trip and its departure with other passengers for the City of Washington.

For the benefit of Society members and guests, the Inspection Visit Committee had provided an exhibition of sky-writing during which the skillful pilot executed the initial letters of the Society in the sky.

TWO PROMINENT FIGURES IN THE VISIT TO THE NAVAL AIRCRAFT FACTORY

J. H. Geisse Was Chairman of the Pennsylvania Section Committee That Had Charge of the Inspection Trip. Capt. G. C. Westervelt, U. S. N., Manager of the Factory, Acted as Host to the Visiting Members of the Society and Delivered an Address of Welcome

Capt. G. C. Westervelt, Construction Corps, U. S. N., manager of the Naval Aircraft Factory, through whose courtesy the inspection visit was made possible, delivered the address of welcome.

After leaving the Navy Yard, the entire party visited the exhibits at the Transportation Building of the Sesquicentennial Exposition.

SPEAKERS AND CHAIRMEN THANKED

Society Members Appreciate Services of Aeronautic Meeting Participants

It has been said that the material that was presented at the technical sessions of the Aeronautic Meeting set a new standard for meetings of this kind. It is not an easy task to prepare and present an engineering paper that will be at once interesting and valuable for the information that it contains. Society members wish those who participated in the technical sessions of the Aeronautic Meeting to realize that their services were highly appreciated. Following is a list of the authors and speakers.

AUTHORS AND SPEAKERS

Hon. Hiram Bingham
Hon. F. Trubee Davison
E. T. Jones
Charles H. Keel for Dr. Adolf Rohrbach
Dr. George W. Lewis
C. T. Ludington
Hon. William P. MacCracken, Jr.
G. J. Mead
L. G. Meister
H. C. Ritchie
Lieut-Com. C. E. Rosendahl, U. S. N.
W. L. Smith
Hon. E. P. Warner
Commander E. E. Wilson, U. S. N.
Lieut. L. M Wolfe, U. S. A. for Capt. W. H. Murphy, U. S. A.

To the chairmen of the three technical sessions, Alexander Klemin, Arthur Nutt and W. B. Stout, and also to Grover C. Loening, who acted as toastmaster at the Aeronautic Banquet, a word of appreciation is due.

PENNSYLVANIA SECTION ASSISTS

Enthusiastic Members Big Factor in Aeronautic Meeting Success

Congratulations are in order for W. B. Stout, Paul Henderson, Glenn L. Martin, Ralph Upson, E. P. Warner, and J. E. Whitbeck, members of the Committee that planned the Aeronautic Meeting.

Great credit is also due the Pennsylvania Section Committees of which E. W. Templin was general chairman. The members of the various local committees listed below showed cooperation of a rare variety. It was largely on account of cooperation that involved a great amount of work that the various events of the Meeting were so eminently successful. The following members are deserving of especial mention:

RECEPTION COMMITTEE

A. K. Brumbaugh, *Chairman*

B. B. Bachman
R. W. A. Brewer
J. H. Geisse
A. Gelpke
C. T. Ludington
H. S. Meese
H. F. Pitcairn
N. G. Shidle

INSPECTION COMMITTEE

J. H. Geisse, *Chairman*

R. W. A. Brewer
N. T. Brown
C. S. Fliedner
J. B. Hill
A. Atwater Kent
H. H. Platt
J. W. Smith
W. J. Swift
Commander E. E. Wilson, U. S. N.
Capt. G. C. Westervelt, U. S. N.

PUBLICITY COMMITTEE

N. G. Shidle
A. Denham

HOUSING COMMITTEE

O. M. Thornton

STUNT COMMITTEE

E. L. Clark, *Chairman*

E. A. Corbin, Jr.	H. S. Meese
J. H. Geisse	A. G. Metz
A. Gelpke	C. M. Young

SECRETARY WARNER FETED

Complimentary Dinner Honoring Navy's Assistant Secretary Tremendous Success

Not often are Society members privileged to have one of their active associates appointed to high government office, as was Hon. E. P. Warner, assistant secretary of the navy in charge of aviation. Especially pleasing was this appointment because of the great amount of enthusiastic work that Mr. Warner has accomplished in the Society during the last few years and because of the very high regard in which he is held by his fellow-members in the Society.

A complimentary dinner to celebrate Mr. Warner's appointment and to honor him in his new capacity was arranged by Robert E. Wilson and his committee, and was held at the Penn Athletic Club, Philadelphia, on the evening of Sept. 3. This dinner was attended by nearly 200 members and guests who derived considerable enjoyment from this social feature.

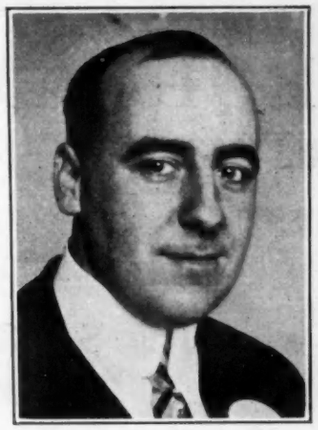
The names of those who sat at the speakers' table are as follows: B. B. Bachman, W. G. Brown, A. K. Brumbaugh, C. F. Clarkson, Admiral H. I. Cone, Dr. H. C. Dickinson, L. D. Gardner, George W. Lewis, Grover C. Loening, C. M. Manly, Arthur Nutt, W. B. Stout, E. P. Warner, and R. E. Wilson.

Robert E. Wilson, chairman of the committee, in his remarks as toastmaster, mentioned the very important accomplishments of Secretary Warner and reviewed in a very refreshing manner the contacts that he has established in Society work and the high esteem with which all his acquaintances regard him.

George W. Lewis, executive secretary of the National Advisory Committee for Aeronautics, mentioned in his address the very effective and fundamentally sound support that Secretary Warner has provided for every undertaking with which he has become affiliated. Lester D. Gardner, who has been in close touch with the work of Mr. Warner at the Massachusetts Institute of Technology, reviewed his work there, congratulated him upon his future outlook and felicitated him upon his appointment. C. F. Clarkson, secretary of the Society, spoke feelingly of Mr. Warner's work in connection with the activities of the Society, expressed sincere hope for his future successes and remarked, in closing, his gratefulness for Mr. Warner's unfailing efforts in the Society's interests, admiration for his achievements and the fact that the members and all his friends love him for the man he is. Professor Prescott, of the Massachusetts Institute of Technology, conveyed to Mr. Warner the congratulations and best wishes of the faculty of that institution and of its alumni.

A. K. Brumbaugh introduced an original feature in the form of the launching and christening of the good ship Edward P. Warner into the uncharted spaces of naval aeronautics. The scenario for Mr. Brumbaugh's intensely amusing demonstration included the presentation to the new secretary of devices and instructions that would assist him on his perilous voyage. Among the useful instruments that were presented were a swivel chair orientator, a retrospective telescope and a chronometer.

With his usual modesty, Secretary Warner responded to the remarks that had been addressed to him with an interesting discussion of the manner in which Society members and engineers in general can cooperate most effectively with the Navy Department and Government branches. He expressed his thorough belief in a brilliant future for aviation and expressed his great appreciation for the wonderful reception that he had received from his fellow-members.



R. E. Wilson

Hon. E. P. Warner

THE TOASTMASTER AND THE GUEST OF HONOR AT THE WARNER DINNER

A leather-bound volume bearing Secretary Warner's initials in gold and with suitably engrossed sentiment included on its pages, was autographed by those in attendance at the dinner, and presented to Secretary Warner as a memento of the occasion.

Following is the committee personnel under whose responsibility the Warner Dinner was carried through with great success:

Robert E. Wilson, *Chairman*

W. G. Brown	C. L. Lawrance
A. K. Brumbaugh	G. W. Lewis
H. M. Crane	G. C. Loening
H. C. Dickinson	C. T. Ludington
Paul Henderson	Glenn L. Martin
A. W. Herrington	G. J. Mead
C. F. Kettering	Arthur Nutt
S. M. Kraus	W. B. Stout

IT WON'T BE LONG NOW!

Meeting of, by and for Production Men Scheduled for Chicago, Sept. 21 to 23

A glance at the condensed program, presented herewith, of the Production Meeting, will reveal the scope and the intensely pertinent subject matter that will be offered for the benefit of production men who will gather at Hotel Sherman in Chicago, Sept. 21 to 23 inclusive. In formulating the program and in obtaining the speakers, Vincent P. Rumely, of the Hudson Motor Car Co., and the members of his Committee, have succeeded in scheduling papers of very broad interest which will be presented by men who will be recognized as authorities along the various lines under consideration. Conveyors, gear production, inspection, and machine tools will be the foci toward which discussion will be directed. Three factory inspection visits and a Stag Carnival will complete the program.

The American Society for Steel Treating will be in convention in Chicago during the Production Meeting and will present its National Steel and Machine-Tool Exposition, which should be of great benefit to the members of both Societies. Invitations that have been interchanged between the Societies assure a hearty welcome to members of the American Society for Steel Treating and of this Society to participate in all activities of both organizations.

CONVEYORS

Paul Phelps and N. H. Preble, of the Mechanical Handling Systems, Inc., have prepared a paper of uncommon interest dealing with conveyors as purely transporting agencies. The

THE PRODUCTION MEETING

HOTEL SHERMAN SEPT. 21 TO 23 CHICAGO

MISS THIS AND YOU'LL MISS *SOMETHING!*

THE STAG CARNIVAL

CHEZ PIERRE SEPT. 21 CHICAGO

The Production Meeting's Great Social Event

Make Your Reservations Now and Avoid the Rush!

talk will consider the general problem and its economic solution and will be illustrated by diagrams and photographs of installations operating in various plants.

Clarence A. Brock, of the Miller-Hurst Corporation, describing types of conveyor that have been found serviceable to the automotive industry, will consider the more important engineering principles of selection and design.

Gears

Gear Steels and the Production of Automobile Gears will be the topic presented by Walter G. Hildorf and John Bethune, of the Reo Motor Car Co. Several types of steel will be discussed with reference to such points as selection, heat-treatment, warpage, and inspection, and an outline will be given of manufacturers' practices in making automobile gears.

Charles L. Cameron, of Gould & Eberhardt, will present some very pertinent material in his paper entitled Automobile Gear Production.

Inspection

A. H. Frauenthal, of the Chandler Motor Car Co., in speaking on the topic, Production along the Line, will discuss methods of increasing the output per inspection man-hour by time studying inspection operations and, where possible, putting inspection operations in a production line.

A vitally interesting feature of the Inspection Session will be a symposium at which a number of persons well qualified to discuss the subject will tell about special inspection devices that have proved helpful in automobile work. Speakers participating in the symposium will be A. R. Fors, of the Continental Motors Corporation; P. W. Rhame, of the A. C. Spark Plug Co.; J. B. Scott, of the Yellow Sleeve Valve Engine Works; C. S. Stark, of the Packard Motor Car Co.; and R. R. Todd, of the Oakland Motor Car Co.

Machine Tools

Two interesting papers, containing much valuable material, will be presented at the Machine-Tool Session. E. R. Stoddard, of the Studebaker Corporation of America, will discuss What Goes Wrong with Machine Tools in Automobile Production, and O. C. Kavle, of Manufacturers' Consulting Engineers, will tell about Fitting the Machine Tool to the Job.

Inspection Visits

An opportunity will be given to all those attending the Production Meeting to visit the plant of the Nash Motors Co. at Kenosha, Wis., the afternoon of Wednesday, Sept. 22, having been set aside for this trip.

Cordial invitations have been extended by the International Harvester Co. and the Yellow Truck & Coach Mfg. Co., for our members to visit their plants, and many will avail themselves of this opportunity on the afternoon of Thursday, Sept. 23.

The Stag Carnival an Unparalleled Social Event

Describable only in superlatives will be the Stag Carnival scheduled for the evening of Sept. 21, at Chez Pierre, perhaps the best known of the exclusive carbaret clubs in the Chicago district.

And sure enough it will be exclusive for members of the Society and guests on the evening of the Carnival. Taliaferro Milton and his committee of Chicago enthusiasts have arranged a special program of entertainment that will extend throughout the dinner-period, and then some, for the amusement and edification of the happy throng.

It may be stated that the whole affair is being designed along the lines that will without doubt make a strong appeal to the men who attend. So, just picture in your mind what would please you most at the Stag Carnival and then rest assured that T. Milton and his committee will produce it.

Reservations for the Stag Carnival are already in great demand. The accommodations at Chez Pierre are limited. It is suggested, therefore, that all who wish to participate in this brilliant event forward their applications at once, using the blanks that have been transmitted with the Sept. 4 issue of the Meetings Bulletin.

An Open Meeting

The Production Meeting will be an open meeting. Persons who are not members of the Society are cordially invited to attend the technical sessions and will be admitted upon payment of a nominal registration fee of $1. Members of the American Society for Steel Treating will be admitted free of charge upon showing their badges.

Reduced Fares Offered

For those who will proceed to Chicago by rail, the fare-and-one-half privilege will be available for members of the Society and members of their families. Enclosed with the Sept. 4 issue of the *Meetings Bulletin*, was a certificate allowing this privilege. Attention is called to the fact that the reduced rate will not be in effect on certain of the limited trains. The ticket agent should be consulted in this regard.

Hotel Accommodations

Usually those who attend National Meetings of the Society desire to be accommodated at the hotel that serves as headquarters for the meeting. Consequently, Hotel Sherman will doubtless house a large majority of these visitors. Other hotels, listed in the order of their proximity to headquarters

in Chicago, are: Bismarck, Brevoort, Morrison, Palmer, Congress, Blackstone, and Drake.

Tools in Operation

The Chicago Municipal Pier will accommodate one of the largest and most interesting expositions of its kind ever held, the National Steel and Machine Tool Exposition of the American Society for Steel Treating. Over 300 exhibits will show the raw material as it passes through various processes to become the finished product.

Scores of machine tools will be shown in actual operation; also other exhibits such as those of heat-treating equipment will be demonstrated under working conditions. In short, the Exposition will provide an unparalleled opportunity for observing the most uptodate equipment under the most favorable environment.

The Committees

The Production Meeting will not come into action without the able efforts of a number of the Society's most enthusiastic members, and several others who are interested in the Society's activities. The following are deserving of especial mention:

PRODUCTION MEETING COMMITTEE

V. P. Rumely, *Chairman*

George Babcock	R. R. Keith
Eugene Bouton	Joseph Lannen
W. G. Careins	L. F. Maurer
C. B. Durham	T. Milton
A. H. Frauenthal	P. J. Moohan
Paul Geyser	Louis Ruthenburg
R. M. Hidey	P. L. Tenney

RECEPTION AND ENTERTAINMENT COMMITTEE

Taliaferro Milton, *Chairman*

C. J. Blakeslee	C. A. Peirce
W. J. Buettner	F. G. Whittington
Lee Oldfield	R. E. Wilson

FACTORY INSPECTION COMMITTEE

O. W. Young, *Chairman*

P. J. Moohan, Robert Stortz, J. W. Tierney	Visit to Nash Motors Co.
Paul H. Geyser, F. D. Gaskill, Lee Oldfield	Visit to Yellow Truck & Coach Mfg. Co.
R. R. Keith, D. P. Baker, J. S. Erskine	Visit to International Harvester Co.

NATIONAL MEETINGS COMING

November and December Meetings on Transportation and Service and Tractors

After the Production Meeting the next event on the National Meetings Calendar will be the Automotive Transportation and Service Meeting that will take place in Boston on Nov. 16, 17 and 18, with the Copley-Plaza Hotel as headquarters. J. F. Winchester, Standard Oil Co. of New Jersey, with a committee of men who are familiar with many phases of operation and maintenance, has scheduled a program that will be of particular interest to operators and those interested in automotive transportation, especially by motorcoach, truck and rail car. Individual sessions will be devoted to such topics as motorcoach and truck operation and maintenance, freight handling, tires, and construction. An inspection visit to the Cambridge maintenance plant of the Standard Oil Co., and a Transportation and Service Banquet will be included in the program.

Tractors

On Dec. 1, 2 and 3, with the sessions under the direction of this Society on the last day, the Tractor Meeting will be held at the Hotel Sherman in Chicago in cooperation with the American Society of Agricultural Engineers. Among the

PRODUCTION MEETING PROGRAM

Time and Place

The Production Meeting will be held at the Hotel Sherman, Chicago, Sept. 21, 22 and 23. The Society and the American Society for Steel Treating are cooperating in arranging the week's events that include, in addition to the Production Meeting, the Eighth Annual Convention of the American Society for Steel Treating and the National Steel Exposition of the latter Society.

Tuesday, Sept. 21

Morning—CONVEYOR SESSION

Transportation by Conveyor—Paul Phelps and N. H. Preble, Mechanical Handling Systems, Inc.

Conveyors Used in the Automotive Industry—Clarence A. Brock, Miller-Hurst Corporation

Afternoon—GEAR PRODUCTION SESSION

Gear Steels and the Production of Automobile Gears—Walter G. Hildorf and John Bethune, Reo Motor Car Co.

Automobile Gear Production—Charles L. Cameron, Gould & Eberhardt

Evening—THE STAG CARNIVAL—Chez Pierre.

Wednesday, Sept. 22

Morning—INSPECTION SESSION

Inspection Along the Line—A. H. Frauenthal, Chandler Motor Car Co.

Symposium on Special Devices for Automobile Inspection:—A. R. Fors, Continental Motors Corporation; P. W. Rhame, A. C. Spark Plug Co.; J. B. Scott, Yellow Sleeve Valve Engine Works; C. S. Stark, Packard Motor Car Co.; and R. R. Todd, Oakland Motor Car Co.

Afternoon—Inspection Visit to Nash Motors Co., Kenosha, Wis.

Evening—Smoker and Frolic given by the American Society for Steel Treating

Thursday, Sept. 23

Morning—MACHINE-TOOL SESSION

What Goes Wrong with Machine Tools in Automobile Production—E. R. Stoddard, Studebaker Corporation of America

Fitting the Machine Tool to the Job—O. C. Kavle, Manufacturers' Consulting Engineers

Afternoon—Inspection Visits to International Harvester Co. and Yellow Truck & Coach Mfg. Co.

All technical sessions will be open to members of the Society of Automotive Engineers and the American Society for Steel Treating. Non-members will also be welcome; they will be charged a registration fee of $1.

NATIONAL MEETINGS CALENDAR

PRODUCTION MEETING AND EXPOSITION—Hotel Sherman, Chicago—Sept. 21 to 23

TRANSPORTATION AND SERVICE MEETING—Copley-Plaza Hotel, Boston—Nov. 16 to 18

TRACTOR MEETING—Hotel Sherman, Chicago—Dec. 1 to 3

ANNUAL DINNER—New York City—January, 1927

ANNUAL MEETING—Detroit—January, 1927

topics to be discussed will be production of tractors and farm equipment, utilization of heavy fuels in tractor engines, industrial application of tractors, and the application of tractors and automotive equipment to road building and maintenance.

Chairman O. W. Sjogren and his committee have practically completed the arrangements for the meeting which will be outlined in detail in subsequent issues of THE JOURNAL and in *Meetings Bulletins*.

SEPTEMBER SECTION-MEETINGS

Indiana, Metropolitan and Cleveland Arrange for Attractive Gatherings

The Indiana Section has scheduled for the evening of Sept. 9 a technical session that will be preceded by a dinner. The speaker on this occasion will be H. L. Horning of the Waukesha Motor Co., who will discuss the interesting topic, The Trend of Engine and Vehicle Design.

Sept. 15 is a date that promises to be a memorable one for members and guests of the Metropolitan Section, if the plans outlined in its most recent Booster are realized. Society members, their ladies and guests, according to the announcement, will assemble at the Engineering Societies Building at 6 p.m. on the eventful evening, whence they will be conveyed by motorcoach to the Manhasset Bay Yacht Club at Port Washington, Long Island. The facilities of the Silvertown Cord Orchestra have been engaged to furnish music during dinner and afterward when those so inclined will be able to indulge their desire to dance. Motorcoaches will leave the Yacht Club for the City at intervals, beginning at 9 p.m.

The Cleveland Section has chosen Sept. 16 as the day for their initial meeting of the 1926-27 season. A trip through the plant of the Timken Roller Bearing Co. will take place in the morning; after this visit the Cleveland Section members will be guests of the Timken Roller Bearing Co. at Congress Lake Country Club, where informal sports in the afternoon will be followed by dinner. Due to limited space, it is announced, only members of the Cleveland Section are invited.

Several of the Sections have advised headquarters of plans for October meetings, and the season of 1926-27 among the Society's Sections bids fair to surpass all previous records for successful accomplishment.

SELECTION IN PROFESSIONAL EDUCATION

ENGINEERING is not a sharply defined professional field but one of a wide range of types and levels of activity which should enlist a correspondingly wide variety of individual talents. It needs the 1-talent, the 5-talent and the 10-talent man. The educational scheme, however, seems to recognize and to provide adequately for only the "professional engineer."

A group of facts must be faced realistically and not sentimentally. Throughout the larger part of the Country the engineering colleges have to carry practically the entire responsibility for higher technical education. The prospect of being able to divide the less advanced part of the field with other types of institutions is remote rather than immediate. Present circumstances bring to the engineering colleges a large body of sound human material, impelled by a fairly valid impulse to the engineering field at large but with untried capacity for the more exacting analytical features. Many of the colleges are not free to make a discriminating initial selection from this material, and the few that are free must do so largely on scholastic grounds rather than evidences of aptitude. The result is a large ratio of elimination in course, with only a minority reaching any recognized goal of attainment through a program planned to meet their needs.

Somewhere in the course of a program of professional education for engineering an exacting standard of selection must be applied. If we are free to do it and able to do it intelligently at entrance to college, well and good, but if not then, we must apply it at some later date. If initial selection is impracticable and that many whom we admit are well able to reach an intermediate goal is certain, is it wholly reasonable and fair to recognize only the latter? If we can recognize both the intermediate and final goal and so add an objective of success for many without impairing the good we are able to do for the smaller number who go the whole route, is it gain or loss?

Under the conditions set forth above as premises, we are of the opinion that two alternatives are open to the colleges, one involving highly selective admission and a unitary program and the other involving non-selective or slightly selective admission with a program divided into two or more distinct stages, thus providing both intermediate and final goals and definite time for selective promotion to the distinctly professional stage of work after an ample try-out. My feeling is that the latter plan has possible merits, even when measured solely by the excellence of the final product, which will fully match those of the unitary program based on highly selective admission, and that the two deserve a thorough trial, side by side.—W. E. Wickenden in a report to the Society for the Promotion of Engineering Education.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

RESEARCH DEVELOPS LIGHTING DATA

Reports Include Findings on Glare Principles and on Lamp Construction

Much valuable information has been developed in the course of the headlight research of this Society and the joint research of the Illuminating Engineering Society and this Society. The publication of some of this material was authorized at meetings held during the Summer Meeting at French Lick Springs, Ind. Two reports, one dealing with fundamental principles involved in headlighting and the other with concrete questions of head-lamp construction, are printed herewith.

Dr. Percy W. Cobb, of the lighting research laboratory of the National Lamp Works of General Electric Co., is the author of the report entitled Visual Fundamentals in the Headlighting Problem. It was prepared at the request of the Joint Steering Committee on Headlight Research of the Illuminating Engineering Society and this Society, and summarizes the investigations carried on by a number of research workers, including the author, to determine the effect of glare on vision. Dr. Cobb's report, substantially in full, follows:

VISUAL FUNDAMENTALS IN THE HEADLIGHTING PROBLEM

The visual problem that enters into automotive headlighting is two-fold. It consists first, in getting enough light on the road ahead to permit the driver to see. Second, the headlights of an oncoming machine entering the driver's field of vision, constitute a complication which is undoubtedly the crucial factor in the problem and which in the nature of the case is the only one appropriate to the present report.

A number of investigations have centered about the interference with vision due to the presence of areas of excessively high brightness in the field. The general plan has been to use a conveniently placed test-object as a measure and to note the effect upon visibility of a light-source, which we will call the glare-source, of various intensities and descriptions and having various positions in the visual field. The general plan is simple enough, but the selection of a test-object and the method of measuring the changes in its visibility present a group of problems which are perplexing in the planning of research and bewildering if we attempt to apply the numerical results in practice. With the essentials of the set-up in mind, some of the experimental findings may be touched upon by way of illustration.

The earliest investigation of this problem which approaches completeness is the work of Depène[1] in 1900. He used as the test-object letters of standard design and of various sizes printed upon white card or paper similar to the test-letters of the eye-specialist. Under stated illuminations of the test-object he then determined the size of the smallest letters which could be read by the subject, in other words he measured visual acuity. With glare sources of various sizes and various brightness at different positions in the field of vision he determined visual acuity for a wide range of conditions and drew conclusions stated as follows:

A glare-source in the field of vision may increase visual acuity, as well as diminish it. The former effect takes place when the test-object is well-lighted, or specifically, when the illumination upon the test-object is sufficient to afford the eye more than about one-half its full reading power as measured by visual acuity. As this phase of the results involves only illuminations above, say, 5 foot-candles, it is irrelevant to the present purpose.

On the other hand, it was found that with low illuminations upon the test-object, there was definite reduction in visibility, as measured by visual acuity, and this reduction was found to be relatively greater with (*a*) increase in the brightness or area of the glare-source; (*b*) closer approach of the glare-source to the direction of observation; and finally (*c*) decrease of illumination upon the test-object.

This last fact is especially to be noted, as it will appear of importance later on. In Fig. 1, Depène's results are shown for an angle of 10 deg. between the line of observation and the direction of the glare-source. It is to be noted, that when the illumination from the glare-light upon the eye at this angle is equal to the illumination upon this particular form of test-

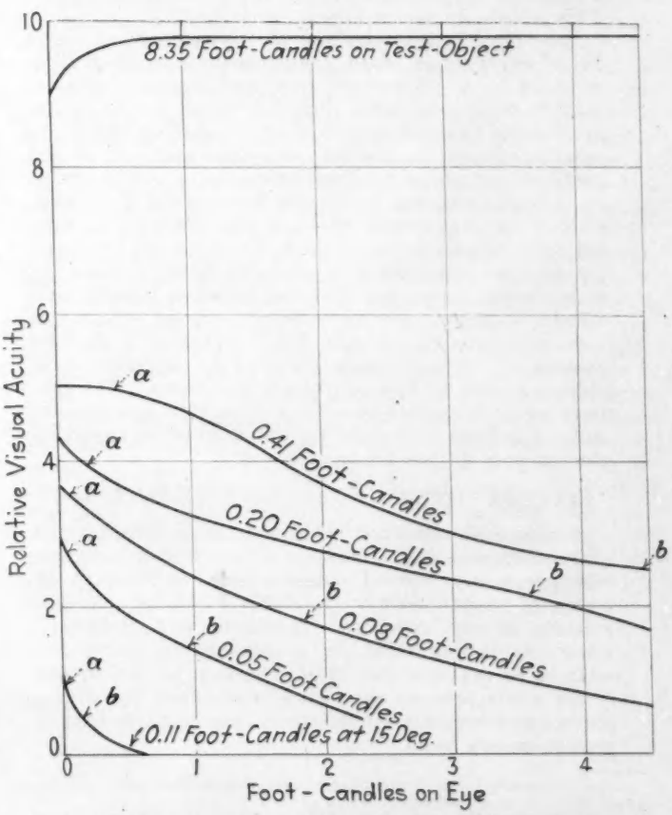


FIG. 1—GRAPHICAL REPRESENTATION OF FINDINGS BY DEPÈNE ON THE RELATION BETWEEN GLARE ANGLE AND GLARE-EFFECT
Results Are Shown for an Angle of 10 Deg. between the Line of Observation and the Direction of the Glare-Source

[1] See *Klinische Monatsblätter für Augenheilkunde*, vol. 38, pp. 289 and 390.

TABLE 1—RELATION BETWEEN THE GLARE ANGLE AND THE GLARE EFFECT

Glare Angle, Deg.	Borschke	Nowakowski	Cobb	Inverse Square
5.....	1,790	...	...	6,400
10.....	600	312	...	1,600
12.....	...	...	240	1,111
15.....	...	239	...	711
20.....	247	183	...	400
25.....	...	...	129	256
30.....	142	133	...	178
40.....	100	100	100	100
50.....	82	78	...	64
60.....	66	61	79	44
70.....	56	43	...	33
80.....	51	25	...	25
90.....	46	13	29	20

object, black and white, little or no impairment of visibility, points marked *a* on the curves, is found. To reduce vision to one-half its protected value, the test-object must have upon it an illumination considerably lower than the illumination upon the eye from the glare-source. It will be seen from the chart that vision is reduced to one-half its protected value when the illumination on the eye from the glare-source is 10 or 20 times that falling upon the test-object, points marked *b* on the curves.

It will no doubt suggest itself, that if the effect of a glaring light-source can be measured by the increase in the size of test-object necessary to maintain visibility, that it should also be possible to measure the effect in another way, namely, by the increase in illumination necessary in order that the identical object may continue to be visible. In fact, from the engineering viewpoint it would seem to be much more useful to measure the glare effect in this way: as the degree to which the light incident upon the object is swallowed up, or nullified by the effect of the glare. This possibility has not been overlooked.

Borschke,[2] in investigating the impairment of vision by glare, used a fixed translucent test-object, illuminated from the reverse side, and measured the extent to which the lamp illuminating it had to be approximated to offset the effect of the glaring light. He was interested in the physiological analysis of the problem and gave relative values only. A group of 12 different persons, under the same glare conditions, showed an impairment offset, in the average, by raising the illumination upon the test-object in the ratio 1.0:4.7, the maximum and minimum being 6.2 and 3.9 respectively, indicating that the variation among individuals in respect to the ratio of increase required is very moderate, in spite of the fact that the absolute amount of light initially required by different individuals varied as 64:1 in the extreme cases. The subjects were of various ages from 12 to 60 years, having various defects in refraction which were corrected by glasses used during the experiment.

Relation Between Glare-Effect and Angle

Borschke also worked out the relation between the glare-effect and angle, between 5 and 90 deg. Depène had previously worked out the angular relation in terms of visual acuity. In 1911, I worked out the relation in my own eye.[3] Luckiesh and Holladay,[4] using the veiling effect as a measure of glare, are inclined to evaluate the effect inversely as the square of the angle between the line of vision and the glare-source, and recently Nowakowski[5] has published some results on this point.

[2] See *Zeitschrift für Psychologie und Psychologie der Sinnesorgane*, vol. 34, p. 1, and vol. 35, p. 161.

[3] See *American Journal of Physiology*, November, 1911, p. 76.

[4] See *Transactions of the Illuminating Engineering Society*, March, 1925, p. 232.

[5] See *American Journal of Hygiene*, January, 1926, p. 1.

The last named has stated his results in a form that is comparatively simple to interpret. He worked with a fixed test-object at reading distance, 13 in. Test letters were used, of a height to subtend an angle of 16 min. at the subject's eyes, equivalent in size to about three times the eye specialist's nominal normal. The amount of light on this test-object necessary for clarity of vision was used as the measure of visibility under no-glare and glare conditions.

Briefly, it was found that with a glare-light at 26 in. from the eye, and 40 deg. away horizontally from the line of the test-object, the necessary increase in illumination of the test-object in foot-candles was almost uniformly 1.38 per cent of the candlepower of the glare-source, or more fundamentally stated, 6.50 per cent of the illumination upon the eye due to the glare-source, over a range where glare-source varied from 10 to 400 cp. and shed from 2.13 to 85.40 foot-candles illumination upon the eye.

Table 1 gives the relation between the angle made by the glare light with the line of direct vision and the glare-effect, arbitrarily placed equal to 100 per cent at the 40-deg. angle:

The following comments are apropriate in regard to the figures given in Table 1:

(1) Borschke used light as the measure of glare and specifies neither the size of the test-object nor any absolute photometric value. It nevertheless appears from the results that the object was large enough, and the initial illumination upon it consequently sufficiently low to exhibit marked depression in visibility and hence large increases in the necessary addition of light

(2) Nowakowski gives two series of results with a glare-source shedding respectively 30.0 and 7.5 foot-candles illumination upon the observing eye. The absolute increases in the amount of light added to offset the effect of these of course are different, but they agree closely as percentages based on the 40-deg. value

(3) Cobb estimated the values of visual acuity with a constant brightness of test-object, after the manner of Depène. The values stated above are: the increase in any linear dimension of the test-object over its no-glare value, the increase for 40-deg. glare being arbitrarily selected as the base

(4) The inverse square of the angle declines too rapidly to be accepted as the law, except possibly at angles of 60 deg. or over

About all that can be said of the tabulated results is that the glare effect is small at 90 deg., that it increases at first slowly, then more rapidly, the rate of increase being extreme at the smallest angles. Incidentally, it is to be remarked that the automotive headlighting problem is chiefly concerned with glare angles of 10 deg. and less, and the results available give us scanty information within this range; and it is also to be remarked that extrapolation is dangerous.

The work of Depène upon this subject will be well worth a careful study. Speaking from memory, as his communication is not at present accessible, he presents a series of relations between glare-angle on the one hand, and size and illumination of the test-object on the other, which includes both the phase principally discussed here, and the phase in which the test-object is small and is seen under higher illuminations, in which instead of impairment, the glare-light actually enhances visibility.

Thus the results obtained in this sort of work will depend much upon the test-object, which in turn determines what the initial, no-glare, illumination shall be

which is critical for vision; and the results will depend also upon our choice of the various possible measures of the glare-effect: whether we measure the increase in the necessary amount of light on the test-object; or the increase in its size under identical light; or, last, and technically the most difficult, whether we use as a measure the time that the test-object has to be exposed.

Difficulties of Choosing Test-Object

One more difficulty is encountered in the attempt at an analytical solution of this or almost any other lighting problem. It is the question: what shall we choose as a test-object which shall be representative, and which shall afford a solution appropriate to the purpose in hand? An examination of the objects that must be seen under the proposed lighting situation is naturally the logical beginning of an answer to this question. But right here I ask: will a person who has driven an automobile at night attempt to describe any one object that could be used as a critical test of the headlighting of his machine? Such a person or persons may exist, but I am not included in that class.

Just to indicate what the difficulty is: the laboratory experiments above described were all conducted with test-objects limited to two dimensions in space, lying in a plane normal to the line of vision. Under such conditions, where the test-character is seen by differences in reflection or transmission of the surface, to say that more light affords better visibility is almost axiomatic. The exception to this rule occurs only at intensities far and away beyond the capacity of automobile headlights.

Contrast this, however, with the conditions encountered on the road, where an object is often to be seen only against a background that may be some few feet or hundreds of feet more remote. Given a significant amount of light on this background from other sources, the object itself may be almost or altogether independently illuminated by the headlights. There will always be, under such conditions, a critical illumination upon the object, at which it most nearly matches its background and tends to vanish. It becomes more distinct as the illumination upon it either rises above *or falls below* this critical value, and illumination and visibility thus part company instead of going hand in hand.

The foregoing discussion has been written to show the extent of our knowledge of the behavior of vision, as it most closely touches the critical problem of automobile headlighting. No attempt to make it exhaustive has been made; and the numerical data that have been given are perhaps scanty, but are as abundant as will be justified when their variability and lack of intercomparability are considered. In general, the conclusions that can safely be drawn relate to trends rather than to quantities, and for the time at least will have to be accepted as such. The particular range of variables covering the automobile headlighting problem requires further experimental study.

Details of Head-Lamp Construction Studied

One side of the headlight question, basic fundamentals to be considered in framing specifications, is presented in Dr. Cobb's report. Another aspect, the suitability of present head-lamps to meet the existing specifications, was studied by one of the Society's research subcommittees, of which T. J. Litle, Jr., is chairman.

At a meeting of this subcommittee, W. F. Little, of the Electrical Testing Laboratories, presented a brief report on construction problems that should be met to put in effective performance the present joint specifications of the Illuminating Engineering Society and this Society. It contained, among others, the following observations:

> Many devices have the S. A. E. standard mounting but the surfaces of the ball-and-socket joints are such that small movements necessary in aiming are out of the question.
>
> Doors rust very rapidly and for this reason they should be considered seriously. Many of them fit so poorly as to allow dust and moisture to accumulate, thus reducing the reflecting power considerably.
>
> The focal adjustments should be described and examined to see if they will continue to work after an extended period. It is rather rare to find head-lamps that have been in use for a year in which the socket can be moved relative to the reflectors.
>
> The accuracy of alignment of the anchor-pin slots is important, particularly with the dual system of lighting.
>
> The question of whether a transverse adjustment should be supplied to take care of variations in lamp construction should be considered.
>
> The accuracy of reflectors appears to be deteriorating, as they do not seem to be so well-constructed as those made some time ago.
>
> The road tests are, of course, very important but decidedly matters of opinion, though it is perfectly true that many defects will never show up on a new lamp without an actual endurance-test.

Other members of the subcommittee spoke of possible improvements in lamp mountings and in the seals of lamp-doors. Emphasis was laid on the necessity for strong and accurate socket-mounting and for reflectors constructed so as to resist deformation through handling. Heavier construction in springs designed to keep bulbs in place was advocated, and the insertion of the lamp in the reflector from the apex instead of from the open end of the parabola was studied. Accuracy in lamp construction was also discussed, and the question raised as to the inspection practice followed by manufacturers.

Much thought was given to the adjustment of head-lamps. What precautions are, or should be taken, by the car builder, the dealer and the owner to see that head-lamps are throwing the illumination where legal requirements, and those of safety, demand? Often the car owner, being inexperienced, does not secure desirable results in his efforts to adjust his own lamps. The difficulty of even such a simple operation as changing lamps was given as the probable cause for much one-light driving. A continual educational campaign will undoubtedly have to be waged to keep the car owner in touch with the need and means for keeping his lamps properly aimed. In connection with the maintenance of correct adjustment, a fixed-focus mounting was considered and thought to be impracticable, but an adjusting device that can be locked after it has served its purpose was recommended.

YALE TRANSPORTATION SURVEY

IN a book entitled Transportation which has been printed privately for a committee of Yale University, is given a summary of the results of the field investigation into the present status of transportation study and research as disclosed by an examination of technical schools, colleges, universities, and research institutes, as well as corporate, public and governmental agencies concerned with transportation. The sub-title of the publication is A Survey of Current Methods of Study and Instruction and of Research and Experimentation.

In this volume Victor Topping and S. James Dempsey, Strathcona Memorial Fellows in Transportation in Yale University, make the following comments as authors:

> The history of the development of the North American continent is a history of the development and improvement of the means of transport. An understanding of the distribution of productive effort throughout the Country and of the territorial division of labor is dependent upon a clear conception of the relation of the means of transportation to the sources of raw material and the finished product. The unraveling of many of the problems of social life is to be found in a grasp and solution of the broad problems of transportation, while the future development of the Country hinges upon the extension of the margin of production, in itself dependent upon the progress and extension of transportation agencies and upon the invention of more efficient and cheaper methods. In fact, an understanding of modern civilization in its economic and social aspects is founded upon an insight into the intricate transportation machine. As a general cultural subject, transportation presents a most fruitful and serviceable study. Therein are focussed human relations and activities, problems of production, marketing, distribution, and consumption, as in few other subjects. Various phases of the subject may be utilized as a living means of illustrating certain engineering principles and methods. Railroad and highway engineering afford perhaps the most fruitful examples of the broad engineering aim and methods of adapting a project to a given set of physical and economic conditions in such a way as to prove of greatest utility.
>
> The outstanding feature with respect to transportation education in the schools of higher learning is the extreme lack of interest that prevails in general. The present mediocre status in both quality and quantity of transportation instruction, engineering or economic, may in large part be due to the retarded demands of the industry for specially trained men.
>
> In all branches of university instruction, outside of the regular basic courses in arts, science and commerce, which are either required or pursued because of their time-honored recognition, students will, as a rule, elect work in which interest is lively and general. In this industrial and commercial age, industries that provide the greatest opportunities for advancement and the play of initiative, in which the need for the extension of knowledge is most apparent, will ever present the strongest attractions to the student, whether he seeks professional knowledge or not. On the whole, the transportation industry has not been of this nature during the last 10 or 15 years. Such developments as have taken place have been chiefly in highway and aerial transport, and in these cases technical progress has been the main feature, the business side lagging behind although now rapidly being accentuated in importance.
>
> Few technical institutions now purport to give specialized undergraduate instruction in transportation subjects for their own sake, and the few that do experience little demand for such instruction, in spite of the fact that they may have excellent facilities. Related to the field of highway transport are the courses in mechanical engineering treating of automobiles and trucks. Very seldom are such courses offered to undergraduates, and only at a very few institutions is extensive graduate work performed. Well-organized graduate courses are offered at the Massachusetts Institute of Technology and at the University of Michigan. Perhaps the greatest development is at this latter institution, where some 80 students are currently enrolled, while in 1921 the enrollment was over 300. Courses are offered in the design and construction of automobile and truck chassis and engines. Extensive laboratory tests are made of all parts. Being situated in the heart of the large automobile industries, the majority of students are rapidly absorbed upon the completion of their studies.
>
> A general introductory course in the economics of transportation should, with due recognition to the importance of the steam railroad, treat of the whole field, including water, highway and perhaps aerial transport. Apart from the intrinsic importance of these carriers, a proper understanding of the railroad business and its problems seems difficult of attainment without their inclusion. The necessity of broadening the conception of transport is becoming more generally recognized, as is evidenced by the courses that are being developed by some institutions.
>
> An exception to the prevailing haphazard methods of providing for graduate instruction in transportation is the curriculum of the Harvard Graduate School of Business Administration. The intention of this course of study is to train students broadly in the important facts and principles of transportation and to impart the training needed for the use of these facts and principles as tools in practice. The training is on a much higher professional plane than is found elsewhere.
>
> Scientific research on the economic side of transportation is rather limited, especially in view of the numerous organizations and institutions in a position to study transportation problems. Much of that which is done is of a decidedly mediocre character. In a few outstanding instances, both in universities and outside, research of a really high order is prosecuted. The carriers manifest, in general, a decided lack of interest in scientific inquiry into the wider economic and social problems that surround the industry. As a first step in the improvement of existing transportation instruction the foundation course must be completely remodeled and brought uptodate.

All forms of transportation agencies were included in the inquiry. A strong plea is made for promotion of scientific knowledge in transportation. The present status of instruction in transportation is described, as well as research in transportation subjects. Needed improvements in transportation study are listed, together with information as to the attitude of transportation agencies and shippers toward the university as an element in transportation education. Several appendices to the main text are included.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S.A.E. Standards Committee and other standards activities are reviewed herein

S.A.E. HANDBOOK TO BE MAILED SEPT. 15

Specifications Adopted at Summer Meeting To Appear in Next Issue

The September issue of the S.A.E. HANDBOOK will be mailed to all members of the Society on Sept. 15, this being the second issue of the Handbook in the bound form. This issue will contain the specifications approved at the Summer Meeting of the Society and adopted by letter-ballot on July 26.

The September and future issues of the S.A.E. HANDBOOK will carry lists of the personnel of the Divisions of the Standards Committee. This will make it possible for members interested in certain specifications to determine immediately what Committee is responsible for the specification and the members thereon. This personnel will be brought uptodate with each new issue of the Handbook and will constitute a more accurate list than the Society has been able to give the members through THE JOURNAL and the Roster.

On page N16 of the September issue of the Handbook will be printed a list of S.A.E. Specifications that have been revised as a result of the Society's action taken at the Summer Meeting and by letter-ballot. This list, which is typical of those that will appear in future issues of the Handbook, will permit members to determine quickly whether any specifications in which they are particularly interested have been changed.

Possibly the most noticeable change in the September issue of the Handbook is the use of an India colored paper for Section N, which contains the general index, miscellaneous information and advertising. It is thought that this paper will make it easier to find the general index. This paper is slightly heavier than the paper used for the text and brings out the half-tone illustrations in the advertising better.

The Handbooks are to be mailed parcel-post, well protected in cardboard containers. Any copies of the Handbook received in poor condition will be replaced by the Society.

STANDARDS APPROVED BY LETTER-BALLOT

The recommendations approved at the Summer Meeting of the Society at French Lick Springs were submitted to a letter-ballot of the voting members during July, the ballots being returnable July 26. The recommendations were approved with the smallest number of negative votes received in recent years, no one specification receiving more than four negative votes. The letter vote is given in the following table; the first column of figures gives the number of members voting in favor of the report; second column, those voting against the report; and the third column, those who did not vote either way.

	Yes	*No*	*Not Voting*
AXLE AND WHEELS DIVISION			
Solid-Tire Felloe and Felloe-Bands	294	1	84
Wood-Spokes for Passenger Cars (Cancellation)	294	1	84
Wood-Spokes for Motor Trucks (Cancellation)	294	1	84
BALL AND ROLLER BEARINGS DIVISION			
Inch Roller-Bearings	316	4	59
Metric Roller-Bearings (Cancellation)	316	4	59
ELECTRICAL EQUIPMENT DIVISION			
Flexible Steel Conduit and Tubing	315	0	64
Generator Mountings	315	0	64
Insulated Cable	314	0	65
Starting-Motor Mountings	315	0	64
Starting-Motor Pinions	314	1	64
Timer-Distributor Mountings	315	0	64
ENGINE DIVISION			
Crankcase Drain-Plugs	308	0	71
Engine Support Arms	309	0	70
Piston-Rings	310	0	69
Piston and Piston-Ring Oversizes	310	0	69
Starting-Cranks	309	0	70
IRON AND STEEL DIVISION			
Molybdenum Steels	313	0	66
LIGHTING DIVISION			
Bases, Sockets and Connectors	310	0	69
Head-Lamp Construction	311	0	68
Head-Lamp Nomenclature	310	0	69
LUBRICANTS DIVISION			
Crankcase Lubricating Oils	305	4	70
MOTOR TRUCK DIVISION			
Hub-Odometers (Cancellation)	279	1	99
PARTS AND FITTINGS DIVISION			
Brake-Lining	301	2	76
RADIATOR DIVISION			
Radiator Nomenclature	305	0	74
Tie-Rod Design	304	0	75
Water-Pipe Flanges	306	0	73
SCREW-THREADS DIVISION			
Castle Nuts	320	0	59
Extra-Fine Thread Fit Applications	320	0	59
Machine-Screw Nuts	320	0	59
Screws, Bolts and Nuts	320	0	59
Screw-Thread Fits and Tolerances	320	0	59
Wrench-Head Bolts and Nuts and Wrench Openings	318	2	59
TIRE AND RIM DIVISION			
Pneumatic-Tire Rim Sections	303	2	74
Pneumatic-Tire Rims for High-Pressure Tires	303	2	74
Pneumatic-Tire Rims for Low-Pressure Tires	303	2	74
TRANSMISSION DIVISION			
Transmission Nomenclature	296	1	82

COOPERATIVE STEEL TESTS BEGUN

Subdivision of Physical-Property Charts To Verify "Frequency" Curves

At the March, 1926, meeting of the Iron and Steel Division it was voted to retain the present physical-property charts until they are revised and extended by the Subdivision on Physical-Property Charts, the charts to be based on "frequency" curves. As the first step in this procedure it was thought desirable to undertake a series of tests of a given

steel, which would definitely determine whether or not the "frequency" curve obtained from available data was truly indicative of its physical properties. It was subsequently decided that the test should be made on S.A.E. Steel 6130, the resulting physical-property curves to be compared with "frequency" curves based on the physical-property data of this steel that have been obtained by the Subdivision.

To make the results of the tests as representative as possible, 36 Division members and others interested in the work agreed to participate in the cooperative tests, the list of those companies participating being as follows:

Allis-Chalmers Mfg. Co.
American Gear & Foundry Co.
Atlas Steel Corporation.
Bethlehem Steel Co.
Buick Motor Co.
Cadillac Motor Car Co.
Carpenter Steel Co.
Columbia Axle Co.
Dodge Bros.
Donner Steel Co.
Eaton Axle & Spring Co.
General Motors Corporation Research Laboratories
Hudson Motor Car Co.
Hupp Motor Car Corporation
Illinois Steel Co.
International Harvester Co.
Interstate Iron & Steel Co.
International Nickel Co.
Midvale Steel Co.
Packard Motor Car Co.
Pittsburgh Crucible Steel Co.
Reo Motor Car Co.
Stanley P. Rockwell Co.
Henry Souther Engineering Co.
Studebaker Corporation of America
Timken-Detroit Axle Co.
Timken Roller Bearing Co.
Union Carbon & Carbide Research Laboratories
United Alloy Steel Corporation
Vanadium Corporation of America
Watertown Arsenal
Westinghouse Electric & Mfg. Co.
White Motor Co.
Willis-Morrow Co.
Willys-Overland Co.
Wyman-Gordon Co.

The steel was furnished by the United Alloy Steel Corporation, Central Steel Co., Bethlehem Steel Co., and the Interstate Iron & Steel Co., and was shipped to Chairman Watson for cutting and keying the blanks. Twelve 1-in. round test-blanks were sent by Mr. Watson to each individual cooperating, the blanks being marked as follows:

A-1	B-1	C-1	D-1
A-2	B-2	C-2	D-2
A-3	B-3	C-3	D-3

The instructions for carrying out the tests were as follows:

TESTING INSTRUCTIONS

(1) Analyze bars A-1, B-1, C-1 and D-1 for
Carbon
Manganese
Phosphorus
Sulphur
Silicon
Chromium
Vanadium
(2) Heat and quench all test-bars as follows:
(*a*) Heat to 1600 deg. fahr.
(*b*) Hold for 15 min. at that temperature
(*c*) Quench in water
(3) Draw as follows:
(*a*) The four bars marked "1" at 800 deg. fahr. for 1 hr.
(*b*) The four bars marked "2" at 1000 deg. fahr. for 1 hr.
(*c*) The four bars marked "3" at 1200 deg. fahr. for 1 hr.
(4) After drawing cool all bars in air
(5) Grind flat surface on side of all bars near center of length and make Brinell, scleroscope and Rockwell tests approximately 1 in. from end
(6) Machine to standard 0.505-in. tensile test-bar; threaded ends preferred, but not essential
(7) Make standard tensile-test determining
(*a*) Yield-Point or Drop of Beam
(*b*) Ultimate-Strength
(*c*) Per Cent Elongation in 2 In.
(*d*) Per Cent Reduction of Area
(8) In report on results submit the following information:
(*a*) Type of tensile machine used and rated capacity
(*b*) Speed of tensile machine
(*c*) Sketch of test-piece employed

The decision to develop charts based on "frequency" curves was made by the Division after it was agreed that the charts now printed in the S.A.E. HANDBOOK indicate the worst possible conditions only, whereas charts based on "frequency" curves indicate the values most likely to obtain in the average heat-treating department.

The present physical-property curves are based on minimum figures for the tensile-strength, yield-point, reduction of area, and elongation, based on the following considerations, the heat-treatment being constant:

(1) The lowest yield-point and tensile-strengths are produced with steels at the bottom of a given range in carbon
(2) The lowest reduction in area and elongations are produced with steels at the top of a given range in carbon

It is expected that the results of the cooperative tests will be available early in October so that a meeting of the Iron and Steel Division can be held at that time to decide whether the present basis for the physical-property charts should be discarded in favor of "frequency" curves.

BALLOON-TIRE SIZES LISTED

The recommendation of the Tire and Rim Division adopted at the Summer Meeting of the Society required that the Standards Department determine what sizes of low-pressure tire were used for the rims specified so that those sizes could be listed as general information, not as S.A.E. Recommended Practice.

The passenger-car and tire manufacturers were canvassed, in accordance with the recommendation of the Division, replies being received from 41 passenger-car and 10 tire makers. Only tire sizes were included that were used by at least two car builders. The Division recommendations, as adopted at the Summer Meeting, but extended to give the tire sizes to be included on the basis stated, are given in the accompanying table, which will appear in the September issue of the S.A.E. HANDBOOK and will constitute the S.A.E. Recommended Practice for Low-Pressure Pneumatic-Tire Rims.

LOW-PRESSURE PNEUMATIC-TIRE RIMS

Nominal Rim Diameter, In. (Tire Seat Diameter)	Nominal Rim Width, In.	Nominal Tire-Sizes Used, In.[1]
21	3½	29x4.40, 30x4.75
20	4	29x4.75, 30x5.25, 30x5.77, 32x6.00
21	4	31x5.25
20	4½	32x6.20
21	4½	31x5.25, 33x6.00
21	5	33x6.00, 33x6.75

[1] Tire sizes are not a part of this specification, but are given to show the nominal tire-sizes used on each rim.

PRODUCTION MEETING ON SEPT. 22

A dinner-meeting of the Production Division of the Standards Committee will be held on Wednesday evening, Sept. 22, at the Hotel Sherman, Chicago, during the Society's Annual Production Meeting. The Annual Convention of the American Society for Steel Treating will be held in Chicago at the same time.

The plan is to have the members of the Society's Production Committee that is now being organized to develop production activities in a general way in cooperation with the Standards, Research, Sections and Meetings Departments meet with the members of the Division at that time.

The Stationary and Rotating Equisignal Beacon

By Capt. W. H. Murphy, U. S. A. and Lieut. L. M. Wolfe, U. S. A.[1]

Aeronautic Meeting Paper *Illustrated with* Charts, Diagrams and Photographs

ABSTRACT

THE equisignal method of airplane signaling consists in receiving signals, sent out by one or more transmitting stations, alternately on two loops the planes of which differ by a certain angle. If the signals obtained on the two loops are equal in intensity, the bisector of the angle between the loops will correspond to the line of sight or of wave propagation. In the development of the apparatus described in this paper, the fundamental idea made use of was that of the old Telefunken compass, which was later used to a considerable extent by the German Navy during the war as an aid to the flight of Zeppelins in their raids on England, and in which the transmitting system consisted of a number of similar directional antennae that could be thrown into the circuit in succession and had directional effects differing in orientation by 10-deg. steps. To overcome the difficulty of keeping such an antenna system in balance, Bellini and Tosi in 1907 patented an antenna system consisting of two directional antennae set at right angles to one another and independently excited by a rotatable coupling-device known as a "goniometer," the physical effect of which was the same as that of a large rotatable directional antenna or loop having the same dimensions as the two component antennae or loops, and which therefore served the purpose more simply and better than the Telefunken device. Use was also made of an idea contained in a German patent, which consisted in using two directional antennae, the planes, and therefore the directional effects, of which differed from one another by a certain angle and in sending out the letter n (— .) in Morse code on one antenna and the letter a (. —) on the other, it being evident that the two letters would be equally strong along a line bisecting the vertical planes of the two antennae in question. With such a device it would therefore be possible to determine the equality of the signals much more closely and easily than to determine the maximum intensity of a single signal. The radio beacon described in the paper is based on the idea of incorporating balanced signals into the Bellini-Tosi system, either to produce rotating equisignals, in place of the original Telefunken rotating signals, or to produce fixed equisignals in any desired direction, instead of along only certain lines depending upon the position of the originally constructed antennae or loops.

Reference is made to the various means of direction finding and their respective advantages and disadvantages, a brief history is given of the history of the development of the radio beacon, its mechanical parts are described, the theory of the goniometer and types of loops are discussed, the equisignal method of signaling is explained, and practical examples of flights are cited.

IN beginning this article on the radio beacon, brief reference will first be made to various means of direction finding and their respective advantages and disadvantages. It is obvious, of course, that position finding is an application of direction finding, because the position of an object can be determined on a chart as soon as its direction from two or more known points has been determined. Any errors met with in determining the directions or bearings consequently enter into the problem of position finding. Direction finding, which is of the utmost importance in air navigation, can be classified into two groups: (*a*) the determinations are made entirely in the aircraft; this immediately but not necessarily implies the presence, with his equipment, of a navigator capable of operating radio apparatus, or an additional operator; and (*b*) the determinations are made at special ground-stations, from which the bearings or position are transmitted to the aircraft; this system implies the use of transmitting and receiving apparatus, an operator on the aircraft and a trained staff on constant duty on the ground.

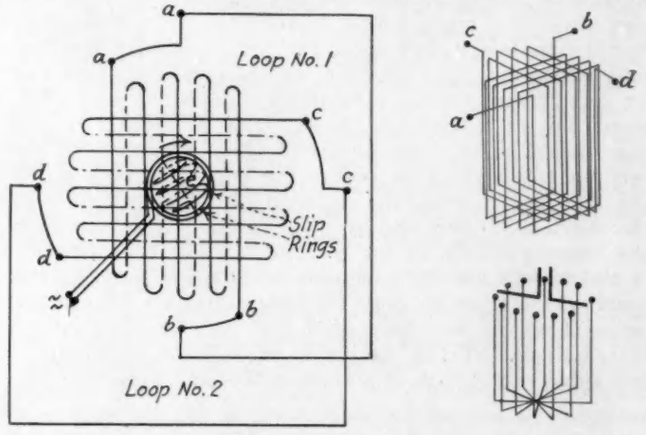


Fig. 1—Diagram Showing Two Loops and Their Coupling-System Composing a Simple Bellini-Tosi Antenna

At the Left Is a Schematic Radio Beacon Coil System; at the Upper Right Is Shown the Inner Goniometer Coil, Corresponding to the Rotatable One-Turn-Coil Primary; at the Lower Right, the External Goniometer Coil, Corresponding to the Secondary or Loop Coupling-Coils

Direction Finding on Aircraft

In the first group, the general procedure is one of the following, depending upon whether the equipment on the aircraft is somewhat complicated or relatively simple. In the first instance the aircraft may be equipped with rotatable or fixed loops, Robinson coils, or a fixed goniometer; if the craft is small, only fixed loops or fixed Robinson coils can be used. The operator or navigator listens to a station, obtains the bearing, by methods to be described later, to within from 2 to 5 deg., makes corrections from a chart that takes into account the errors caused by metallic parts of the aircraft, determines the location of the station from a call-book, marks it on a map, and indicates the obtained bearing by a thread. Should this station be located at the terminal of the

[1] Signal corps aircraft radio laboratory, McCook Field, Dayton, Ohio.

flight, it will suffice to set the course and to make occasional checks on the station in question, it being assumed that the station is in practically continuous operation. If the station is not at the terminal, the operator or navigator will repeat the procedure on another station, put in the new bearing-line and note the point of intersection with the first bearing. Further observations will, of course, make this determination of position more accurate. It must be understood that other errors enter into the procedure; the waves may be distorted at certain times, additional distortion may occur along the coast and the corrections due to local distortion may vary with time and with different wave-lengths. It may be stated that this general procedure was used on the Navy Trans-Atlantic flight, on the Spanish flight to South America and by Amundsen on the Trans-Polar flight. The method has advantages for long flights, as no special stations are required on the ground, it being necessary only to locate the bearing of any station, the call letters and location of which can be determined. Aircraft making such flights will, in general, be spacious, and the additional weight of the personnel will not be of such great importance.

Directional Signals Transmitted from Ground Stations

The aircraft may be equipped with simple receiving apparatus and antenna instead of the more intricate direction-finding equipment. In this case, rotating directional-signals are sent out from certain ground-stations, or beacons, having characteristic calls that are followed by directional signals rotated, for example, in 10-deg. steps and at a constant speed. The procedure in this case would be to listen to one of these stations and determine the bearing by noting the numerical position of the strongest signal, the position of which would give the bearing. If two equally strong signals were obtained, the bearing would be the bisector. Thus, for instance, if the fourth and fifth signals were the strongest, the bearing would be 45 deg. In practice and with certain refinements, an accuracy of 3 deg. can be obtained by this method. If the station is at a flight terminal, it will suffice to fly in such a manner that the same numerical signal will always be the strongest. As a matter of fact, if the beacon is a terminal station, it need not rotate at all, but should be set on the course so that it can be used as an accurate guide. This is exactly what is done at the McCook Field beacon, to be described later. In case the beacon is not at a terminal, the navigator will indicate the bearings on his chart with a thread, as before, and will proceed to obtain the bearings from other similar beacon-stations. The operation is therefore similar to that described in the first case, except that the operation in the airplane is simplified. On the other hand, it requires the continuous operation of a number of automatic or semi-automatic stations. The accuracy of the initial bearing-determinations is slightly less than in the first method. The incidental errors, however, are smaller, so that in the end the results are practically of the same order of accuracy.

Method Used by Zeppelins

This method was used to a considerable extent prior to and during the war by Zeppelins in long-distance flights, and the results obtained were satisfactory, except when the position of the aircraft to the base-line of the various beacon-stations, or compass-stations, as they were called, became too acute, in which case the accuracy of determining the position became rather small. The location of the beacon-stations with regard to the territory to be flown over, therefore, is important. When small aircraft are used, or when the construction is chiefly of metal, loops are less applicable and, in that case, the beacon method would be preferable. In the second group, that is, when the location or bearing determinations are to be made on the ground, the procedure is as follows: The operator, or possibly the pilot, will call the designated control-station by radio; on hearing on OK from that station, he will send a continuous signal on which a number of special stations, connected to the control station by telephone, will obtain their respective bearings; these bearings are telephoned to the control-station, where the bearings are laid out on a chart and the location of the craft is determined. The location thus determined, or the bearing on a definite point, is then telegraphed back to the aircraft for the informa-

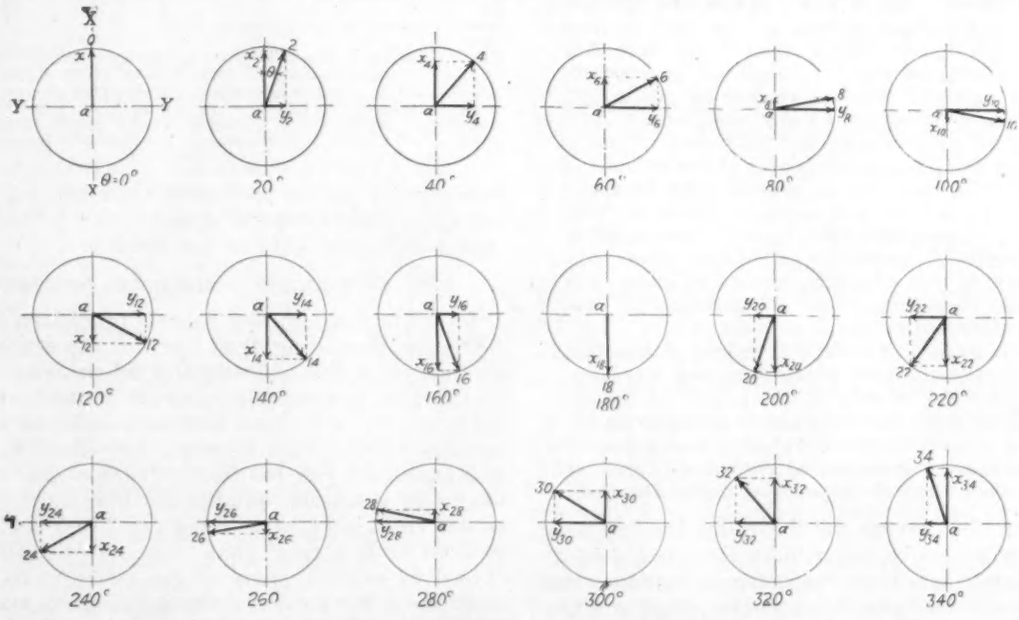


Fig. 2—Chart Showing Simultaneous Currents in the Two Loops *XX* and *YY* and the Direction and Strength of the Resultant Field Maximum
The Position of the Resultant Corresponds to the Position of the Goniometer Coil

tion of the pilot; the operation in the air is therefore simplified to the minimum and the accuracy of determination is most favorable, although errors due to the aircraft antenna are met with. On the other hand, numerous links are introduced that may cause failure or errors. Most essential, of course, is the fact that failure of the aircraft transmitter makes the system inoperative. It is also necessary to keep an expert staff on continuous watch and, even so, if traffic is heavy, considerable delay in obtaining data must be expected. The system has been used practically in marine work, in coast-artillery work and, in Europe, by the Imperial Airways.

Service to Air-Transport Companies

As the service given to air transport companies will apply to definite routes and not to general flying and, especially, as additional personnel cannot be carried on the smaller transport-airplanes without seriously reduc-

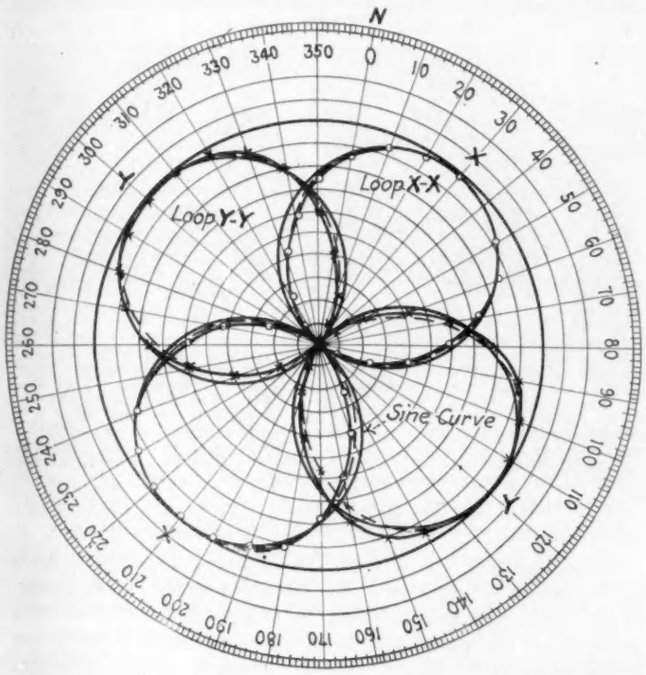


Fig. 3—Chart Showing Actual Current Distribution in Both Loops of the Radio Beacon

The Effect of These Currents in the Two Loops Is To Produce a Resultant Vector-Field in a Direction Corresponding to the Position of the Primary Coil and of an Intensity Equal to the Vector Sum of the Fields Produced by Each Loop; Consequently, the Field Is Always of Unit Intensity

ing the pay-load, it will suffice, obviously, to furnish the pilot with information that will keep him on his route; or, in order to avoid collision, to give him information that will inform him whether he is slightly to the right or to the left of his course. He can, of course, fly over a leader cable or a series of parallel cables; but this is not practicable, except possibly near the end of routes; or he can fly with a fixed loop, so as always to hear certain weak automatic stations along the route. This would be equivalent to the use of blinker lights. Should the pilot be forced, however, to leave his course because of weather conditions, difficulty might be experienced in finding it again. It is also possible, as has been mentioned, to make use of an operating station at the terminal, whereas the aircraft is equipped with a loop receiver. The aircraft can then be flown in such a manner that the terminal will be reached, although the course will be curved, if there is a cross-wind component, unless the drift due to the wind can be determined. Finally, the fixed-beacon

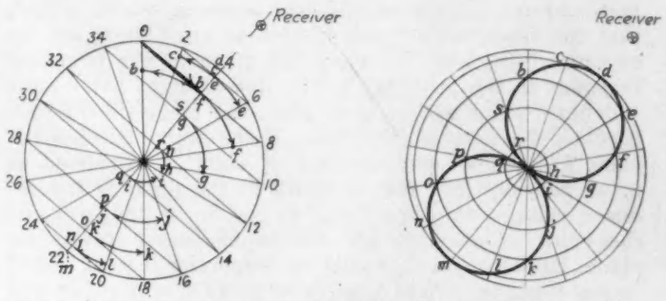


Fig. 4—Method of Obtaining Reception Characteristic from a Rotating Directional Signal

With the Receiver at 40 Deg., the Signal Intensity Due to Signal $a0 = a0 \text{ Cos } 320 \text{ Deg.} = a0 \text{ Cos } 40 \text{ Deg.} = 0.766 \times a0$. Graphically, the Values of Intensity Are Obtained by Projecting $a0$, $a2$, $a4$, $a6$, and so on, on Line 22-a-4 and Obtaining ab, ac, ad, ae, and So On. These Values Are Then Entered on the Chart at the Right as Shown

method can be used; and this has a special advantage in that the drift or effect of the cross wind is automatically compensated for, so that the airplane will actually follow the straight course. It gives the greatest accuracy with the least effort and possibility of error; allows two aircraft to fly in a fog in opposite directions without the possibility of collision; allows a pilot to leave his course to avoid storms, and the like; and yet assists him in bringing his craft back to the course. It may be objected to in that it is not sufficient that a pilot should know that he is on the course, but that he should also know his position in actual flight. The pilot, however, knowing the direction of the wind at various altitudes and localities, both from data obtained before departure and by radio every hour after departure, as well as from the air-speed of the aircraft, can determine with considerable accuracy the ground distance flown. It is evident, therefore, that sufficient information will be available for location purposes, especially if the pilot has an occasional opportunity to check his distance by ground observations.

Means for Obtaining Directional Effects

It will now be of interest to describe briefly the various means by which directional effects can be obtained. These methods may be classified into two groups: namely, directional reception and directional transmission, although the same methods, in general, are applicable to both cases. The basic method depends on the di-

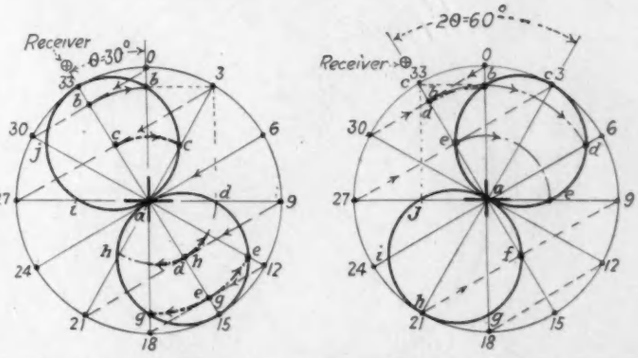


Fig. 5—Chart Showing Graphically the Effect of Reversing the Current in Loop 2-4

In the Drawing at the Left, the Loop 2-4 Is Normal. The Receiver Is at 330 Deg. The Projected Intensity of the Original Signal $a0$ Is ab; the Second Signal $a3$ Is Composed of Value ab in Loop 1-3 and Value ad in Loop 2-4; the Projection of $a3$ Is ac, and So On. In the Drawing at the Right, Loop 2-4 Is Reversed. The Original $a0$ Is as Before; the Projected Value on the Line of Sight Is ab. The Second Signal $a33$ Is Composed of Value ab in Loop 1-3 and Value aj in Loop 2-4. $aj = ad$ but Is in the Opposite Direction. The Projection of $a33$ Is $ac = a33$, and So On. The Effect of Reversing Loop 2-4 Is To Shift the Characteristic for a Given Receiver Forward by 20, or Seemingly To Reverse the Direction of Rotation

rectional characteristics of a loop antenna, which is such that the reception or transmission is greatest in the direction of the loop, or when the plane of the loop corresponds to the direction of the line of sight to or from a definite point and is zero when the plane of the loop is at right angles to this line. If the angle between the plane of the loop and the line of sight is expressed as Θ, we can say that the intensity of the field, or the induced voltage, is proportional to $\cos \Theta$. If the loop and the point in question are not in the same horizontal plane, however, the intensity is proportional to $\sqrt{(\sin^2\beta + \cos^2 \Theta \cos^2\beta)}$, where β is the angle of elevation, as will be explained later. In general, the angle of elevation is small, so that the equation $\cos \Theta$ may be employed, in which case the well-known figure-8, or cosine, characteristic is obtained. It is obvious that the maximum signal can be determined with only fair accuracy, as the intensity variation per degree is slight near the maximum.

Maximum and Minimum Signal Methods

The method making use of this maximum signal determination is known as the maximum signal method and was the first method employed. Its chief drawback is, of course, the lack of sharpness obtainable. The minimum signal method, which consists in determining the zero signal, is preferable, as the rate of change of signal intensity is very rapid and as a sharp zero is therefore obtainable. When little internal noise or radio and ignition interference is encountered, this method is most satisfactory. If this is not the case, the weak signals on either side of the zero will be drowned out so that no greater accuracy is obtainable than with the maximum method. Both these methods were used exclusively prior to and during the first years of the war. To overcome the difficulties mentioned, Robinson, in England, developed a method that was employed with considerable success during the latter part of the war, especially on airplanes on which the minimum method did not give satisfactory results.

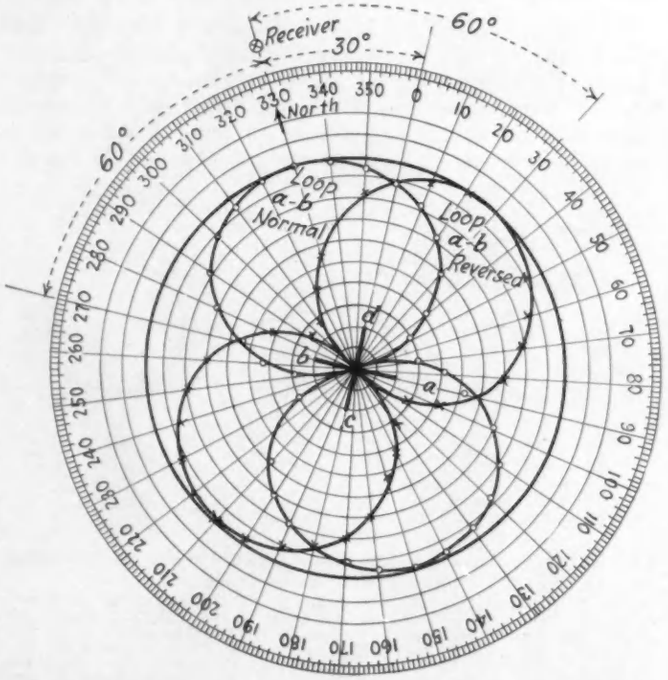


Fig. 6—Chart Showing the Effect of Reversing the Loop 2-4
The Receiver Is at 330 Deg. The Reversal Has the Effect of Moving the Characteristic Forward 2 × 30 or 60 Deg., or Backward 120 Deg. Similarly, the Effect Is Equivalent to Rotation in a Counter-Clockwise Direction

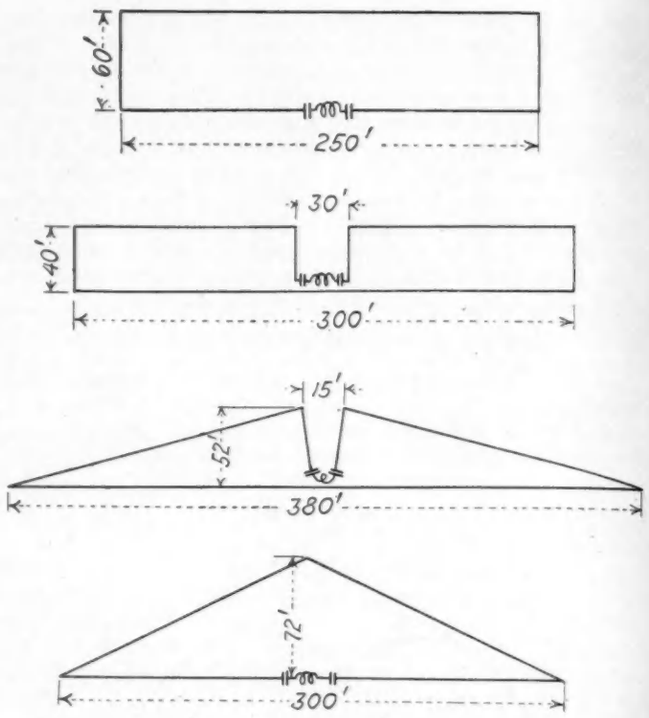


Fig. 7—Types of Loops Used in Experiments
At the Top, the First Square Loop Has an Area of 15,000 Sq. Ft.; Length of Wire, 620 Ft.; λn = 480 m.; R at 1050 m. = 11 Ohms; and L_o = 380μh. In the Upper Center, the Second Square Loop Has an Area of 10,400 Sq. Ft.; Length of Wire, 720 Ft.; λn = 440 m.; R at 1050 m. = 22 Ohms; and L_o = 320μh. In the Lower Center, the First Triangular Loop Has an Area of 9600 Sq. Ft.; Length of Wire, 875 Ft.; λn = 420 m.; R at 1050 m. = 23 Ohms; and L_o = 310μh. At the Bottom, the Second Triangular Loop Has an Area of 10,800 Sq. Ft.; Length of Wire, 640 Ft.; λn = 446 m.; R at 1050 m. = 19 Ohms; and L_o = 320μh. At 200 Miles, the Minimum Signal Operation of No. 1 Requires about 7 Amp.; No. 2, 10 Amp.; No. 3, 11 Amp.; and No. 4, 9.7 Amp. A Vertical Antenna of 70-Ft. Height or 45-Ft. Effective Height Requires Approximately 4.25 Amp. at 1050 m. for Equal Intensity

The Robinson Method

This method, known as the Robinson method, is a combination of the two mentioned above. Essentially, it consists, first, of receiving the maximum signal on a small loop; then a second loop, approximately three times as large as the first and mounted rigidly at right angles to it, is connected in series with the first loop through a reversing-switch. If the first loop is pointed directly at the station, the second loop, obviously, will pick up no signal, so that a reversal of the switch will have no effect on the signal intensity; if, on the other hand, a slight error in the original setting has been made, a certain addition to and subtraction from the original signal-intensity will be noted, depending on whether the induced currents are in, or 180 deg. out of, phase; and an inequality of signal will therefore be found when the switch is reversed. The problem, then, is to alter the position of the loops so that no variation in signal will be obtained when switching takes place. These loops, instead of being rotatable with respect to the airplane, may be built into the plane, in which case the airplane itself must be maneuvered into the correct position.

A similar method consists in receiving the signals alternately on two loops, the planes of which differ by a certain angle. If the signals obtained on the two loops are equal in intensity, the bisector of the angle between the loops will correspond to the line of sight or of wave propagation. This method, known as the equisignal method, is basically the method employed in our radio-beacon transmitter. The last two methods, in their basic

form, have the accuracy of the minimum method and overcome its disadvantages. All, however, have one fault, in that an ambiguity of 180 deg. is possible. This ambiguity is eliminated at once if the bearings are taken on two points, or if the loop station itself is in motion along a course not coinciding with the line of wave propagation.

Types of Antennae

It may be pointed out that a loop is not the only type of antenna that will give directional results. A horizontal antenna, in which the counterpoise and antenna form two symmetrical halves in line with one another, has a characteristic similar to that of a loop and, in fact, was used before loops were used. In this case, if the angle Θ expresses the angle between the line of sight and the antenna system itself, the field or signal intensity is a function of sin Θ. Such a system would, owing to its horizontal dimensions, be practical only when used in connection with short waves. An inclined, or L, antenna

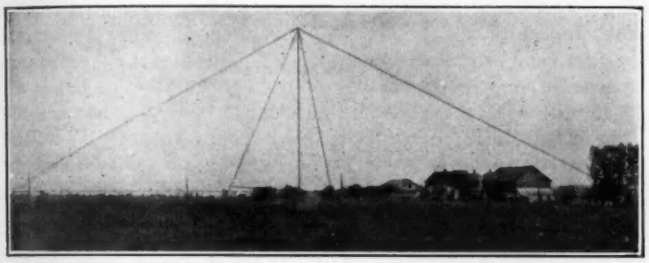


Fig. 8—Triangular Antenna Used at Wilbur Wright Field
The Antenna Was Made of No. 8 Duralumin Wire, Chosen Because of Its Strength and Lightness. This Was Later Replaced by No. 8 Copperweld Wire, as the Former Broke Frequently Due to Vibrational Fatigue

will also give directional results that are functions of Θ, the angle of departure from the vertical plane of the antenna; the angle of elevation β; and the angle of antenna inclination α. A combination of vertical antenna and loop antenna is also possible, and this gives a unidirectional characteristic; unfortunately, however, its sharpness is not great. Excellent unidirectional-transmission results are obtained by the employment of parabolic reflectors, or by combinations of multiple-tuned and parallel reflector-antennae. These latter types classifiable as "beam transmitters," are most efficient and cause less general interference than the loop-type systems. Owing to their physical dimensions, however, which are proportional to the wave-lengths used, they are not applicable to long-wave work, especially if the bearings are to be variable.

As stated before, the method employed at Dayton for flights to or from Dayton uses a directional transmitter that will give a correct indication on any course but can also be used as a rotating beacon, if desired. In the following account, a brief history is given of the development of the beacon, a description of the component parts of the beacon, the theory of the goniometer, a description of the equisignal method, and some practical examples of flights.

History

The fundamental idea made use of was that of the old Telefunken compass, which was later used to a considerable extent by the German Navy during the war as an aid to the flight of Zeppelins in their raids on England. The transmitting system consisted of a number of similar directional antennae that could be thrown into the circuit in succession and had directional effects differing in orientation by 10-deg. steps. Such an antenna

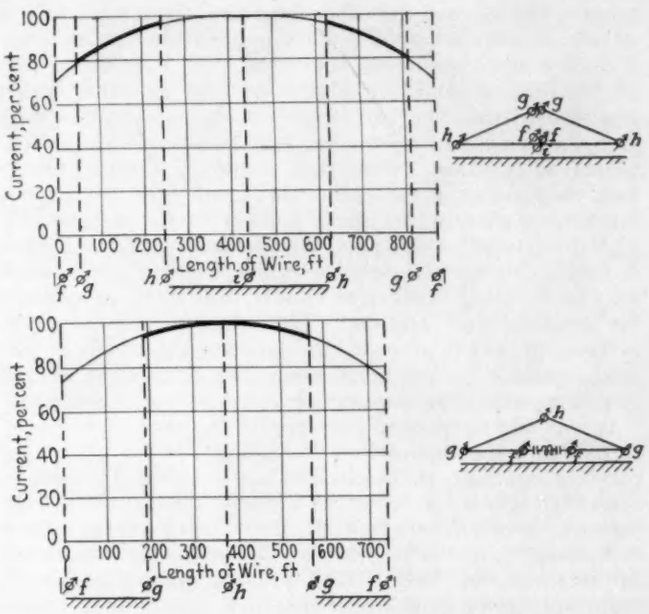


Fig. 9—Current Distribution in Triangular Beacon Loops of the Top-Feed and Bottom-Feed Types
The Bottom-Feed System Was Found To Be Preferable, for a Greater Useful-Current and Smaller Base-Current Are Obtained

system, obviously, was hard to keep in balance, as each antenna unit had to have exactly the same characteristic as the others. To overcome this difficulty, we decided to adopt the antenna system patented by Bellini and Tosi in 1907, which consists of two directional antennae set at right angles to one another and independently excited by a rotatable coupling-device known as a goniometer. This system has exactly the same physical effect as a large rotatable directional antenna, or loop, of the same dimensions as the two component antennae, or loops, and therefore serves the purpose desired more simply and better than the Telefunken device.

In addition to this device, an idea contained in a German patent, granted to O. Scheller in 1907, was also employed. This consisted in using two directional an-

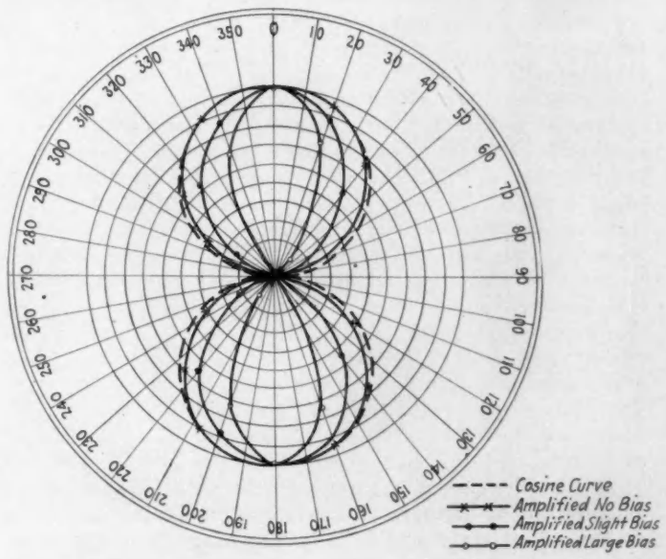


Fig. 10—Chart Showing the Percentage of Deflection at the Receiver from the Radio Beacon
The Broken Line Is the Cosine Curve; the Line Having Crosses Shows the Amplitude with No Bias; That with Heavy Dots, a Slight Bias; and That with Circles, a Large Bias

tennae, the planes, and therefore the directional effects of which, differed by a certain angle from one another. The idea was to send out the letter n (−.) in Morse code on one antenna and the letter a (.−) on the other, it being evident that the two letters would be equally strong along a line bisecting the vertical planes of the two antennae in question. With such a device, it would therefore be possible to determine the equality of the signals much more closely and easily than it would ever be possible to determine the maximum intensity of one signal. It would, further, be possible to make use of the balance zone to fly along a straight course toward or away from the transmitting station. This German patent went farther, in that it proposed the interlocking of the letters a (.−) and n (−.) in such a manner as to form a dash (−) or t, when the two signals were of equal intensity.

It was our purpose to incorporate the idea of balanced signals into the Bellini-Tosi system, either for producing rotating equisignals, in place of the original Telefunken rotating signals, or to produce fixed equisignals in any desired direction, instead of only along certain lines depending upon the position of the originally constructed antennae, or loops. The present radio-beacon has been built up on these basic ideas, as just stated. Prior to the commencement of this work, considerable ground and flight data were obtained at McCook Field and in the City of Washington, jointly by the Signal Corps, the Air Service and the Bureau of Standards, on the Marconi-Round type of system, used both as a receiver and as a transmitter. In June 1923, the first satisfactory coupler, or goniometer, was completed locally, after considerable preliminary work on the loops had been carried out.

Description of Goniometer

Fig. 1 shows diagrammatically two loops and their coupling-system composing a simple Bellini-Tosi antenna. Loop No. 1 is connected to coil *a-b* and loop No. 2 is connected to coil *c-d* at right angles, the two coils being placed so that no interaction between them can take place. These two coils constitute the secondary of the coupling-system or goniometer. In the center is shown coil *e*, the primary of the coupling-system, which is itself connected to the high-frequency source. This coil is rotatable and will therefore induce different amounts of current in the two secondary coils and their loops, depending on the position of the coil *e* with respect to the secondary coils. The current induced in any coil is the maximum when the two coils are parallel to one another, or are in the same plane, and zero when they are at right angles to one another. Instead of employing an interior rotatable coil, *e*, a complete exterior system of open coils, 10 deg. apart, that can be closed or thrown into the circuit by a rotating arm, as shown in the upper right corner, has also been used. By doing so, absolute accuracy of the different operating-positions was assured. The secondary coils, *a-b*, and *c-d*, are of equal dimensions and were constructed as shown in the diagram at the lower right.

To show what the currents induced in the two secondary coils and in the loops are, and in what manner they vary, we have prepared the diagrams shown in Fig 2. As stated before, the maximum current, which we will call "unit" current, is induced in that coil which is parallel to the primary coil, while zero current is induced in the coil at right angles to it. The diagram at the upper left corner, therefore, shows unit current induced in the coil or its loop *XX*, and zero current in the coil or loop *YY*, it being understood that the rotating coil is initially in a plane parallel to coil *XX*. If the current in the primary coil is kept constant, and the coil is rotated into a new position differing from the original position by the angle Θ, or in this case by 20 deg., it is obvious that a certain amount of current is induced in both the secondary coils and in their loops, the amount of the current actually being unit current times cos Θ in coil *XX* and unit current times sin Θ in coil *YY*. The current in each loop, therefore, is equal to the projection of the unit current on the *XX* and *YY* axes; and this has been shown graphically in the remainder of the diagrams.

Current Distribution in the Loops

The actual current-distribution is shown in Fig 3. The effect of these currents in the two loops is to produce a resultant vector-field in a direction corresponding to the position of the primary coil and of an intensity equal to the vector sum of the fields produced by each loop; consequently, the field is always of unit intensity. The result is therefore the same as if a single loop, as *XX*, had in each case been rotated into a position corresponding to the new position of the inner coil. We can therefore logically speak of a "phantom loop" whose position is identical with the position of the primary coil and whose current is constantly of unit intensity.

It will be noted that the current in coil *XX* has a definite directional relation to the current in coil *YY*; that the current when shown to be flowing upward in *XX* is shown flowing to the right in coil *YY* and when shown flowing down in coil *XX* is flowing to the left in coil *YY*. This is important, as a reversal in the relation will cause considerable confusion, unless it is understood.

It is evident that if we have a fixed-loop transmitter and move a receiver around it at a constant distance, the variations of the signal intensity will be the same as if the receiver were fixed and the phantom loop were allowed to rotate about its axis.

Determination of Signal-Intensity Characteristic

If signals are transmitted, beginning with the north position, and if the receiver is located at a bearing of 40 deg., the first signal, obviously, would not be the maximum; the signal would increase in intensity from the start until the plane of the loop corresponded to the plane of sight. Fig. 4 shows graphically how the signal-intensity characteristic would now be determined: the original would be of an intensity equal to the projection of *ao* on the line of sight in the diagram at the left, or equal to *ab*, which is *ao* cos Θ. If this intensity is then measured off along the plane of the loop in the original position, we will have the new point *b*, which is then transferred to the diagram at the right. This point is situated on the new figure-8 characteristic, as are all other points determined in a similar manner. The rotation of the characteristic obtained is seen to be dependent on and coincident with the position of the receiver, and it is obvious, therefore, that if the numerical position of the maximum signal is noted, the bearing of the receiver with respect to the transmitter will be known. In the case under consideration, if signals are sent out for every 10 deg., beginning with north, the maximum signal would be found to be the fourth signal after the original signal. The bearing will therefore be known to be 40 deg. Actually, the original signal is made a non-directional or call signal so that it will always be heard. It is then followed by the directional signals at evenly spaced time-intervals.

The effect of current reversal in one component loop is shown in Fig. 5. The drawing at the left is a theoretically obtained directional diagram for a receiver

located at 330 deg., the diagram having been obtained in exactly the same manner as before. The drawing at the right is the form of the diagram that would be theoretically obtained, if the current in the coil or loop, indicated by the heavy horizontal line, which is the same as the coil *a-b* of Fig. 1, had been reversed. An incorrect bearing would, of course, be indicated corresponding to 30 or to 210 deg. The effect of this error in current relation, is therefore, to shift the characteristic by twice the angle Θ, or, from another point of view, to reverse the direction of rotation of the phantom loop. Fig. 6 shows the actual measurements made at a receiver situated at 330 deg., both for normal and for reversed conditions, to

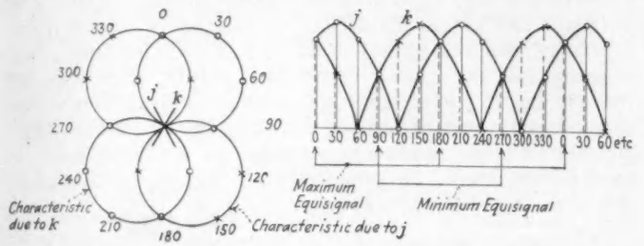


FIG. 11—CHARACTERISTICS FROM TWO PHANTOM LOOPS DIFFERING IN ORIENTATION BY 60 DEG.
It Is Assumed That the Receiver Rotates around Stationary Loops or That the Receiver Is Stationary and the Loops Rotate in a Clockwise Direction. Signals Sent Alternately on Loops *j* and *k* May Consist of a Dash on Each Loop, or an A (.—) on One Loop and an N (—.) on the Other

show the correspondence of the theoretical results with those obtained in practice. A test of this sort will, in practice, immediately show the installing personnel which connection is the correct one to use.

TYPES OF LOOPS

Before proceeding farther, it may be well to show the types of loops experimented with. (See Fig. 7). The first type of loop set up at Dayton, which is shown at the top, was rectangular in form and was used solely for fixed equisignals. The loop in the upper central drawing was the first loop made up for use in the Bellini-Tosi antenna; but, as considerable difficulty was experienced in keeping two of them well balanced, they were soon replaced by the centrally-fed triangular loops, shown in the lower central drawing, which were found to be more easily kept in shape and had the additional advantage of requiring only one antenna-mast and, consequently, of interfering less with flying. The central top-feed feature was used in spite of the additional length of wire required, because it was hoped that some type of uniform ground-return system might be developed. This was possible on even ground but, when the station was transferred to Wilbur Wright Field, uneven ground was encountered and a metallic return became necessary to overcome the distortion due to different capacity-effects between the loops and the ground. This effect was further reduced by running the return wires horizontally about 8 ft. above the ground. The central top feed was not employed at Wilbur Wright Field, an antenna as shown in the bottom drawing being built. This antenna, which is shown in Fig. 8, was made up of No. 8 duralumin wire, chosen because of its strength and lightness. The wire was later replaced by No. 8 copperweld wire, as the former broke frequently due to vibrational fatigue.

Complete data were obtained on these loops. The amount of current in each loop for satisfactory operation to an airplane 200 miles distant was calculated and found to be substantially correct; similarly, the current required

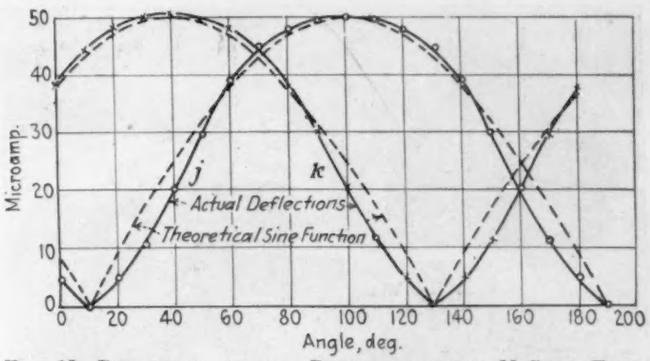


FIG. 12—DEFLECTION OF THE RECEIVER AT THE McCOOK FIELD LABORATORY DUE TO THE ROTATING BEACON AT WILBUR WRIGHT FIELD, 7 MILES DISTANT
The Solid Line Shows the Actual Deflections; the Broken Line, the Theoretical Sine Function

in a 70-ft. non-directional antenna to give the same field-intensity at that distance was also determined at that time. Among numerous other tests conducted at that time was a series to obtain data on the actual current-distribution along loops of the top-feed and bottom-feed types, in order that a better knowledge of the actual useful-current in the inclined legs and the useless current in the base might be obtained. (See Fig. 9.) From this study the bottom-feed system was seen to be pref-

FIG. 13—CONSTRUCTION OF A SIMPLIFIED GONIOMETER
This Goniometer Did Away with Jumpers by the Simple Expedient of Using Two Arms That Could Be adjusted with Respect to One Another, So That It Became Possible To Shift the Angle between Phantom Loops at Will and To Determine by Test Which Angle Would Give the Best Results. In this Way, 60 Deg. between the Arms Was Finally Found To Give the Best Results, at Least with Simple Dash Signals

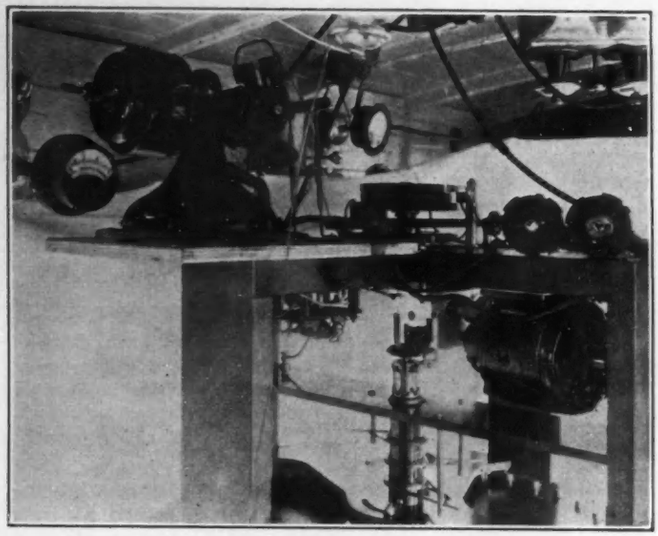


FIG. 14—TRANSMITTER USED ON WILBUR WRIGHT SET
This Shows a Close View of the Relays and of the Signal Cams That Produce the Interlocking Letters

erable, for a greater useful-current and smaller base-current are obtained. This fact was substantiated by reception tests.

CURRENT INDUCED IN CROSSED LOOPS

We will now revert to the current induced in each of two crossed loops by the rotatable goniometer coil. It will be remembered that the current in the first loop was equal to unit current times cos Θ, while the current in the second loop was equal to unit current times sin Θ (see Fig. 2). The resultant antenna-current characteristics would therefore be two figure-8's at right angles to one another. Fig. 3 shows the actual antenna-current characteristics of this type obtained on the Wilbur Wright loops. The axes are rotated through 30 deg. because the loops are set up in this position due to the character of the ground, which made this position the best for symmetry. The resultant phantom loop is in no way affected by the actual position of the crossed loops, as is shown by what follows. Reception measurements, obtained by a radio receiver with a micro-ammeter in place of a headset, show deflections dependent on the field intensity produced by the phantom loop; consequently, if a receiver is, for instance, set up north of the transmitting station and the phantom loop is rotated in a clockwise direction beginning with north, we shall, as previously explained, obtained characteristics of a form approximating a figure-8, as shown in the outer full-line characteristic of Fig 10. It was found that, by adjusting the grid bias of the detector tube, the form of the reception characteristic could be controlled within limits, and that it could actually be sharpened, at the expense, however, of signal strength. A BC-8a amplifier was converted, in order that the grid bias could be altered at will. The two inner full-line characteristics show the resultant effect of this change of bias, the value being drawn on a percentage basis to obtain a uniform scale.

EQUISIGNAL TRANSMISSION

So far, no mention has been made of the application of the Scheller or equisignal system to our beacon. It will be remembered that the rate of change of signal intensity at and near the maximum is low, and that the rate of change increases rapidly to either side of the maximum. If signals from two characteristics differing from one another by about 60 deg. could be compared, a great increase in the sharpness and ease of balance would obviously be obtained; and this is exactly what is done in the equisignal method. Fig. 11 shows the characteristics from two phantom loops, j and k, differing in orientation by 60 deg. If the loops rotate in a clockwise direction and the receiver is fixed, or vice versa, the signals from loops j and k in the first position will be equal, as the receiver, assumed to be north of the station is then on the bisector. If the phantom loops are both rotated through 30 deg., the signal from loop j will have reached the maximum and the signal from loop k will have dropped to one-half this value. At 60 deg., the signal from loop j will be of the original intensity and the signal from loop k will be zero. The diagram at the right shows the points at which the intensities of the signals are equal. It also shows that there is sufficient difference between the maximum equisignals and the minimum equisignals to allow them to be differentiated. In practice, the minimum equisignals are used, for they are sharper.

INTENSITY OF SIGNALS AT DISTANCE OF 7 MILES

Fig. 12 shows deflections obtained 7 miles from the transmitter, due to the two phantom loops j and k. This curve also shows the close correspondence of the theoretical values of intensity. The bearing of the receiver was actually 70 deg., thus demonstrating the extreme accuracy with which the balance can be obtained. To obtain 10-deg. steps, separate open goniometer coils were built up to 10 deg. apart that could be closed at will. In addition to this, it was also necessary to pro-

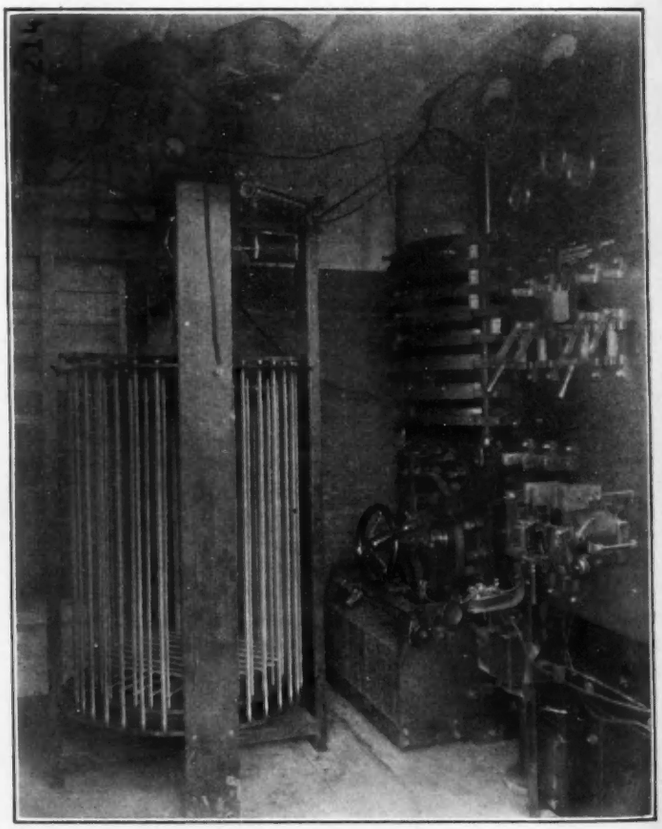


FIG. 15—TRANSMITTING SET USED AT WILBUR WRIGHT FIELD
This Illustration Gives a General View of the Goniometer and of the Set

duce a second phantom-loop; and, in this case, a 40-deg. shift was thought to be satisfactory. To obtain this result, additional contacts were inserted and bridged over to points removed by 40 deg. In operation, signals were sent out in groups of two as, for instance, 340 deg. and 20 deg.; then 350 deg. and 30 deg.; then 0 deg. and 40 deg., and so on. If, for example, the signals of the second group were of equal intensity, the bearing of the station would be known to be 20 deg. The 40-deg. angle between phantom loops was not necessarily the best angle with which to work and, as sparking between jumpers developed due to the high potentials, a new and more simple goniometer was made up, as shown in Fig. 13. This did away with jumpers by the simple expedient of using two arms that could be adjusted with respect to one another, so that it became possible to

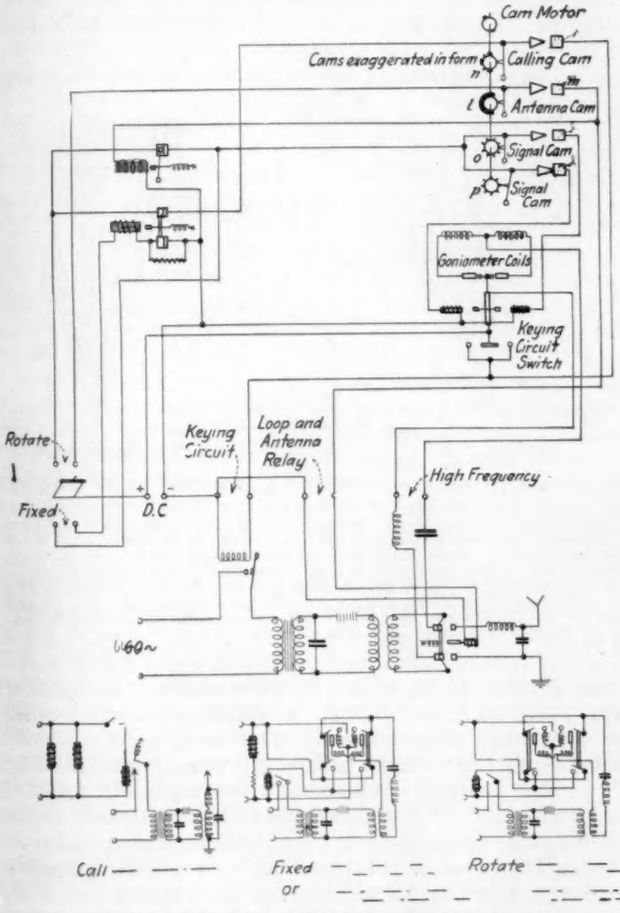


FIG. 16—DIAGRAM OF RADIO BEACON TRANSMITTER

In Case Rotating Equisignals Are Desired, the Switch at the Left Is Thrown Up and the Goniometer Motor with Its Cam Is Started. In the Original Position, Cam *l* Closes Contact *m* and This, in Turn, Opens the Keying-Circuit Relay at the Left; It Also Throws the Antenna into the Circuit and Opens the Primary of the Goniometer. The Cam *n* Is in the Circuit and, by Operating This Calling Cam, the Keying Relay Is Put into Action

shift the angle between phantom loops at will and to determine by test which angle would give the best results. In this way 60 deg. between arms was finally found to give the best results, at least with simple dash-signals.

BEST ANGLE OF FIXED AND ROTATING INTERLOCKING SIGNALS

The best angle for fixed and rotating interlocking signals has been determined to be about 50 deg. By increasing the turns of the primary from one to three,

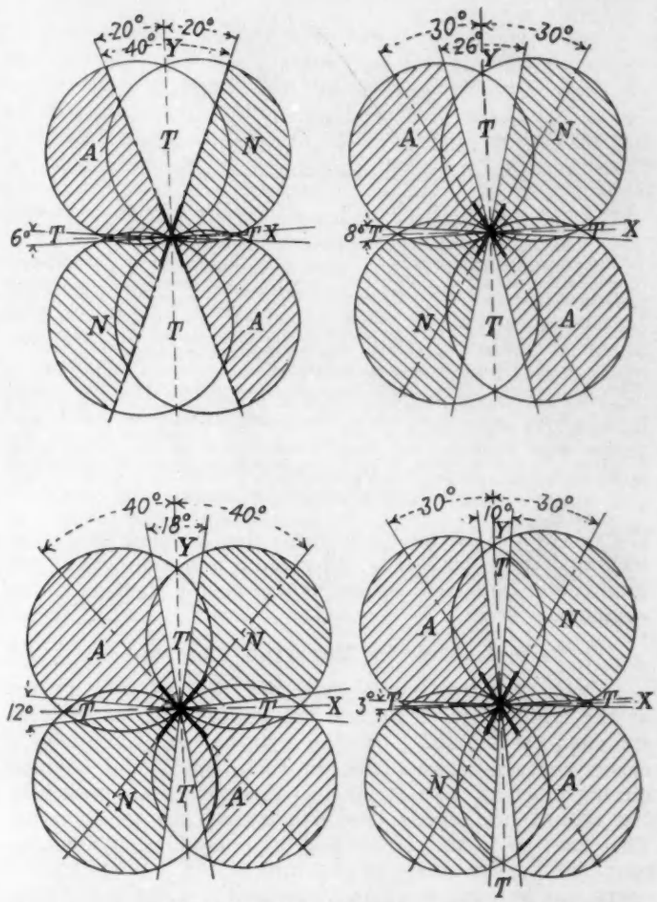


FIG. 17—EFFECT OF THE EQUISIGNAL ZONE ON THE BALANCING OF SIGNALS

Inability To Balance Signals Is a Physiological Effect. In Spite of the Difference in Balance That Can Be Detected by Some Operators Due to Their Greater Experience, a Slight Zone Still Exists Over Which the Dash Signal May Appear Sharp. This Zone Depends on the Angle between the Coils or Phantom Loops. In the Views Shown at the Upper Left, Upper Right and Lower Left, the Exaggerated Distinguishable Ratio Is 1.3 to 1.0, Whereas the Maximum to Minimum Equisignal Ratios Are 2.75, 1.77 and 1.18, Respectively. In the View at the Lower Right, the Practical Distinguishable Ratio Is 1.1 to 1.0 and the Maximum to Minimum Equisignal Ratio Is 1.77 to 1.00

the efficiency of the system was increased from 30 per cent to 41 per cent. For 300 watts set-input, we obtained at first 90 watts antenna-input; with 3 turns, we obtained 123 watts antenna-input.

To make the system entirely independent of the position or orientation of the actual loops, the inner or secondary coil-system was made movable up to plus or minus 5 deg. so that the phantom-loop bearings could be adjusted to correspond to any desired compass-bearings. This was especially necessary if stationary equisignals were to be used, as the course to be followed might differ from the nearest 10-deg. step by 1 deg. or less.

In order to make it possible to operate stationary equisignals, the arms had to remain fixed and it was necessary to replace the keying and contact systems by relays operated by a special cam. It was at this stage that cams for sending the letter a (.—) and n (—.) were made up; they were set at first so that the letter p (.— —.) was produced, but this did not give as much satisfaction as the interlocking letters. When work was begun on the Wilbur Wright set, a new goniometer was built along the same general lines but with more space between the primary and the secondary coils to reduce the capacity coupling. Fig. 14 gives a close view of

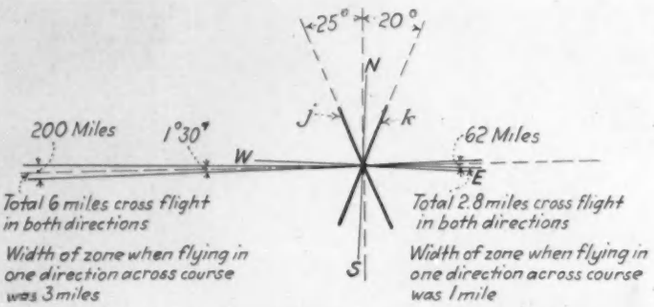


FIG. 18—RESULT OF FLIGHTS MADE ALONG THE MINIMUM EQUISIGNAL LINE OF A 45-DEG. SET OF PHANTOM LOOPS

These Flights Were Made to Points 200 Miles West and 62 Miles East of Dayton. The Loop Input in Both Cases Was the Same, That Is, 500 Watts. On the 200-Mile Flight, a 4-Lb. and on the 62-Mile Flight a 7-Lb. Antenna Was Used. In the 200-Mile Flight, the Width of Zone, When Flying in One Direction across the Course, Was 3 Miles; the Total Cross-Flight in Both Directions, 6 Miles. In the 62-Mile Flight, the Width of Zone, When Flying in One Direction across the Course, Was 1 Mile; the Total Cross-Flight in Both Directions, 2.8 Miles

the relays and of the signal cams that produce the interlocking letters, while Fig. 15 given a general view of the goniometer and set. Fig. 16 shows a diagram of the complete system.

TRANSMISSION OF ROTATING EQUISIGNALS

In case rotating equisignals are desired, the switch at the left is thrown up and the goniometer motor with its cams is started. In the original position, cam *l* closes contact *m* and this, in turn, opens the keying-circuit relay at the left; it also throws the antenna into the circuit and opens the primary of the goniometer. The cam *n* is in the circuit and, by operating this calling cam, the keying relay is put into action. When cam *l* opens, the antenna is again disconnected and the goniometer is put into the circuit, the signal-circuit relay closes and current flows alternately through cams *o* and *p* to the goniometer-coil relay, which controls both the keying circuit and the high-frequency circuit. In fixed equisignal operation, the main switch is thrown down. This opens the lower relay at the left, which in turn opens the circuit to cam *n;* the goniometer shaft is uncoupled, and the arms are set in the direction desired. The circuit to cams *o* and *p* is in operation, and keying to each of the arms now takes place as before.

The balance of signals is never absolutely determinable. It is therefore not correct to speak of an equisignal line, except theoretically, but rather of an equisignal zone. This inability to balance two signals is a physiological effect; persons more experienced in laboratory work will be able to detect slight differences between the intensity of signals before others who are not so expert. With interlocking letters this difficulty is to a great extent overcome, as a wavering tone in the dash easily shows differences in balance that might otherwise have been

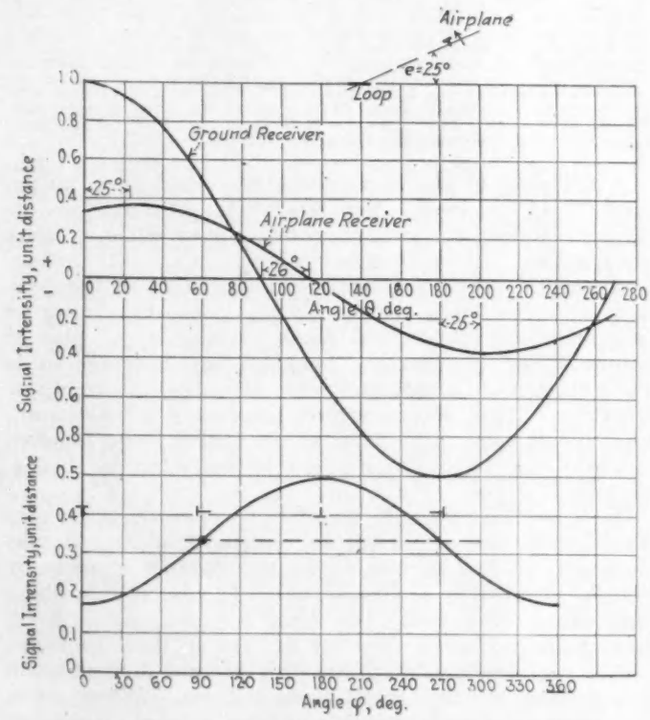


FIG. 19—DIRECTIONAL EFFECT OF AIRPLANE ANTENNA

The Upper Set of Curves Is for the Antenna in the Air with 26-Deg. Distortion and for the Antenna on the Ground with 0-Deg. Distortion. The Lower Curve Shows the Airplane Antenna Characteristic

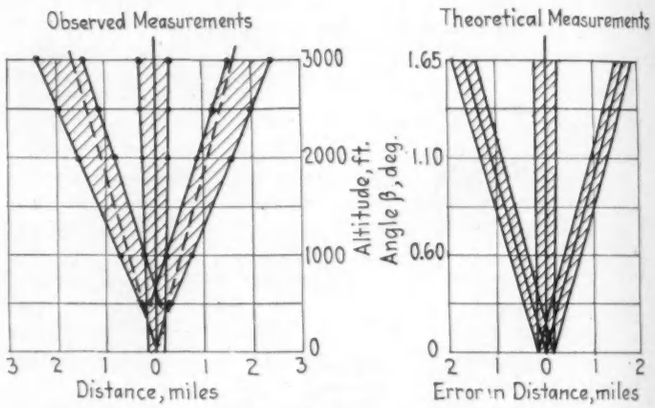


FIG. 20—CHART SHOWING INCREASE IN POSITION ERROR WITH INCREASE OF HEIGHT, IN CROSS FLIGHT

These Observations Were Made in 1921, the Distortion or Shift at Various Altitudes Being Obtained during a Flight of 20 Miles. The Diagram at the Left Is for Observed Data; That on the Right Was Obtained from the Theoretical Formula, Based on the Equation Tan α=Tan ρ/Tan α, α Being 19 Deg. The Central Portion Is for an Airplane in Stalled Flight or Flying Head On. The Dotted Line in the Figure at the Left Is the Center Line of the Theoretical Diagram

detected only by an experienced operator. In spite of this, there is however still a slight zone over which the *t* (–) may appear sharp. This zone depends chiefly on the angle between the coils or phantom loops (see Fig. 17), as the limit of doubt must occur when the ratio of the two signals or components reaches a certain value. When dashes are compared by an inexperienced observer, it is entirely possible that the limiting ratio determinable may be as much as 1.3 to 1.0; even in this case, however, the minimum equisignal is determinable with considerable accuracy, when the loops are separated by 40 deg. When the angle becomes greater, the accuracy of the maximum equisignal improves while the accuracy of the minimum equisignal diminishes, until at 90 deg. both are equal in intensity and accuracy.

ACCURACY WITH INTERLOCKING SIGNALS

Tests made in numerous flights with the interlocking signals show that an accuracy, with 60-deg. separation between arms, of 3 deg. at the minimum and 10 deg. at the maximum equisignal can be obtained. This indicates that a signal ratio of 1.1 to 1.0 can be determined with accuracy. This does not indicate than an error of 3 deg. is expected but that the two limits of the doubtful area subtend such an angle. The limits being easily found, the theoretical equisignal line can be determined

in flight to within 30 min., after a little experience. Fig. 18 shows flights made along the minimum equisignal line of a 45-deg. set of phantom loops. The width of the zone was here determined to be about 1½ deg. in both cases. The accuracy of determination with rotating equisignals is less, as the signals are sent out in 10-deg. steps. It is possible, however, as stated before, to determine the bearing to within 3 deg. by this means, especially when the position of the ship corresponds closely to one of the 10-deg. bearings. In general navigation, an accuracy of 5 deg. will be of value, especially if bearings on three or more stations can be determined so that triangulation will be possible.

Error Due to the Space Characteristic of the Loop and the Airplane Antenna Characteristic

Nothing has been said about an important error that enters into direction finding in space. This error is caused by the polarization of the component fields of the radiated wave. We have carried on considerable work both of a practical and an experimental nature and the results have been found to be in very close agreement. In general, it is sufficient to deal with the loop characteristic on the ground; this is the cosine characteristic previously dealt with. If the total maximum electrostatic-field at unit distance be considered as unity, the field at any point in space can be expressed in terms of angular relations. At any point, this field is, of course, at right angles to the line of sight. It can conveniently be resolved into three components: a vertical component (a), a horizontal component in the vertical plane of sight (b), and a horizontal component at right angles to this plane (c). The vertical component of the electrostatic field has an intensity at any point equal to cos Θ on the ground. The other components are zero, or practically so. As the point of reception is raised by the angle of elevation, called β, the intensity of the vertical field drops until it becomes zero, when $\beta = 90$ deg. The vertical field at any unit distances can therefore be expressed as cos Θ cos β. Similarly, the horizontal electrostatic b varies as cos Θ, but reaches the maximum when $\beta = 90$ deg. The intensity of this field at any unit-distance point is expressed as cos Θ sin β. The second horizontal field c, being at right angles to the first, varies as sin Θ sin β. The actual total field-intensity at any point, therefore, as stated before, is proportional to $\sqrt{(\sin^2\beta + \cos^2\Theta \cos^2\beta)}$ which is the equation of a toroid, the axis of which corresponds to the axis of the loop. This is the form to be expected, as the loop, being symmetrical, has a space characteristic produced by a rotated figure-8, which is a toroid. The relation of the various components is seen to be very simple, and the angle of polarization at any point can be determined without difficulty.

Effect of the Field on the Airplane Antenna

It is most important to show the effect of this field on the antenna of an airplane. If the angle that the airplane antenna makes with the horizontal is denoted by α, and the vertical plane containing the airplane antenna makes an angle ϕ with the plane of sight, ϕ being zero when the airplane is heading away from the ground station, and 90 deg. when rotated 90 deg. counter-clockwise, the vertical field a is a cos Θ cos β. If this field is projected on the antenna in question, it produces a component along the antenna equal to cos Θ cos β sin α. The horizontal field b must first be projected on the vertical plane, giving a component cos Θ sin β cos ϕ, while the field c gives a similar component sin Θ sin β sin ϕ. Each of these components again produces a component along the antenna: the first, cos Θ sin β cos ϕ cos α; the second, sin Θ sin β sin ϕ cos α. The three components give a total field along the antenna that is, by simplification, found to be cos Θ cos β sin α — sin β cos α cos $(\Theta+\phi)$. This formula is the key to the solution of the often noted and discussed apparent shift of an airplane position when the airplane is flying in any direction other than head or tail on.

To show the effect, for instance, of right angle cross-flight, let it be assumed that the airplane is flying at right angles to the loop and in a counter-clockwise direction so that $\phi = 90$ deg. Let it be further assumed that the initial part of the airplane antenna makes an angle $\alpha = 20$ deg. below the horizontal, which is a fair average value for standard light-weight antennae. Further, let the elevation of the airplane be 10 deg., which is a comparatively large angle met with in practice only when the airplane is close to the ground-station. As ϕ is now 90 deg., cos ϕ becomes 0 and the formula simplifies further to cos Θ cos β sin α + sin β cos α sin Θ. Table 1 shows a complete calculation of the field intensity in arbitrary units for a receiver at unit dis-

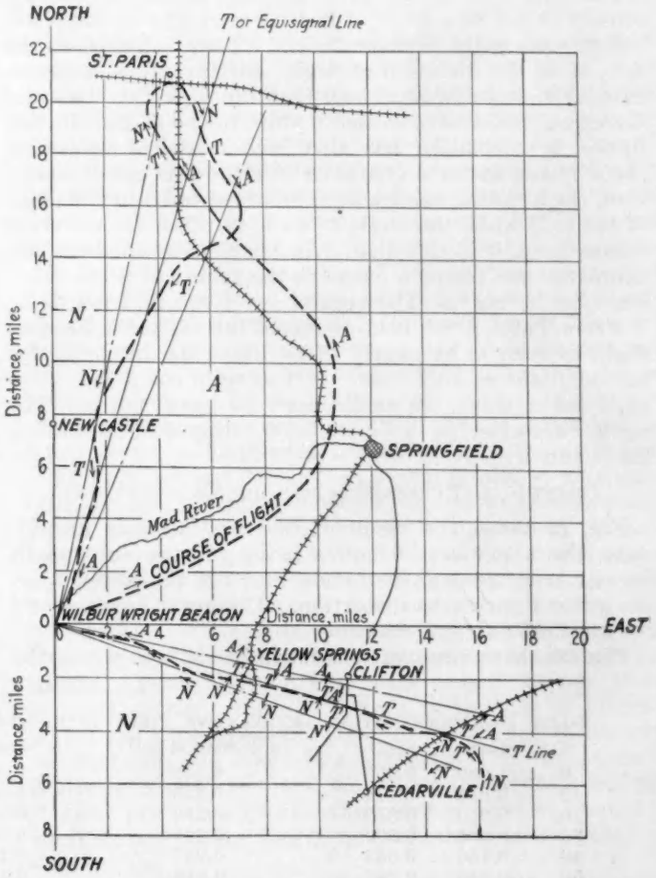


Fig. 21—Course of a Test Flight in Which Both the Minimum and the Maximum Equisignals Were Studied Closely

The Observed Shift and the Calculated Shift for the Height Flown Check within a Fraction of a Mile, While the Width of the Equisignal Zone Was Observed To Be in Very Close Accord with the Width Estimated from a Distinguishable Ratio of Signal of 1.1 to 1.0. In Each Test, the Accuracy of Determining the Equisignal Zone Was within 30 Min. The Antenna Consisted of 40 Ft. of No. 17 Copperweld Wire. The Plumb-Bob Weight Was 7 Lb.; the Velocity, 80 M.P.H.; the Altitude, 2000 Ft.; and the Antenna Angle, α, 85 Deg. The Shift of T from the Correct Position Due to Cross Flight Was Calculated as 0.664 Miles; Measured in Flight It Was 0.700, 0.600 and 0.500 Miles. The Equisignal Zone at the Maximum Was Calculated as 10 Deg. and Was Measured as 8 Deg.; the Equisignal Zone at the Minimum Was Calculated as 3 Deg. and Was Measured as 3 Deg. The Measured Bearing Was Correct to within 30 Min. Shift of T Is a Function of the Height and of the Antenna Angle, Not of Distance. The Width of the Equisignal Zone Is a Function of the Distance Only and of the Angle between the Signal Arms, Not of the Height or of the Antenna Angle

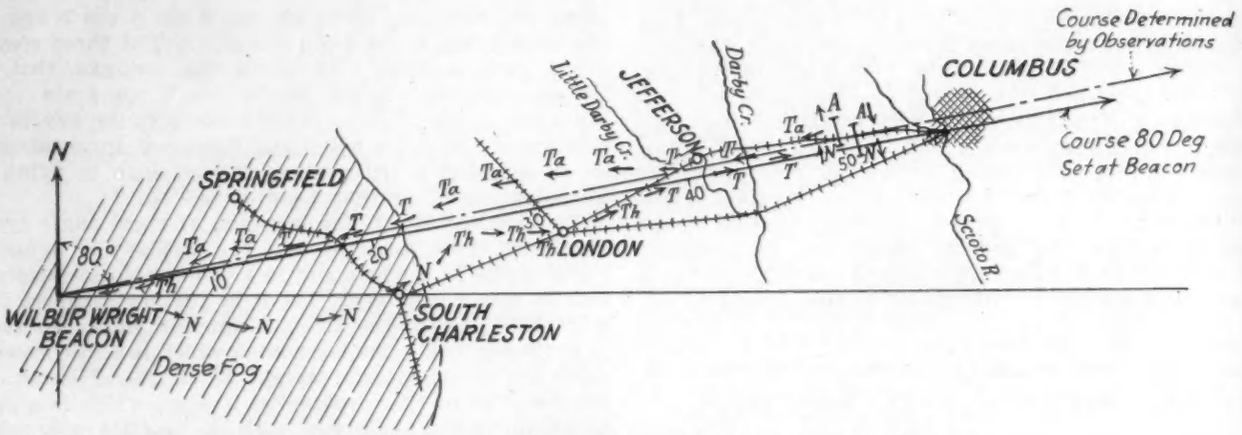


FIG. 22—COURSE OF AN INTERESTING FLIGHT FROM WILBUR WRIGHT FIELD TO DAYTON AND RETURN

The Width of the Zone A to N Was 1.8 Miles at 50 Miles, or 2 Deg.; Width of Zone T_a to T_a Was 0.7 Miles, or 45 Min. Shift of Zone from Cross Flight in One Direction to Cross Flight in the Opposite Direction Was 0.8 Miles, or 50 Min. Error in Bearing, 30 Min., or Error in Position, 0.5 Mile at 50 Miles. The Antenna Consisted of 80 Ft. of No. 17 Copperweld Wire with 7-Lb. Weight. The Altitude at Columbus Was 3000 Ft. During the Fog, at an Altitude of 100 Ft., a 40-Ft. Antenna Was Used

tance. It will be noted that the maximum field-intensity is not now at $\Theta = 0$ deg., as might be expected, but at some point between 20 and 30 deg. A shift to the left, or in the direction of flight, has therefore occurred. Similarly, it could be shown that flight in the clockwise direction would have caused a shift to the right. In this figure, a calculation has also been made, to determine the airplane antenna characteristic for this specific position, the airplane having been assumed to be in the plane of the loop while the angle ϕ has been taken for different values from 0 to 180 deg. As sin Θ now equals 0, the characteristic formula assumes the form $\cos \beta \sin \alpha - \sin \beta \cos \alpha \cos \phi$. The results are given in Table 2.

From Table 2 the field or signal intensity for head-on flight is seen to be nearly three times the intensity for tail-on flight in this case. If we write $\cos \beta \sin \alpha = \sin \beta \cos \alpha \sin \phi$, we obtain $\cot \Theta = \tan \beta / \tan \alpha$. The error, however, is $\phi = 90 - \Theta$; therefore $\tan \phi = \tan \beta / \tan \alpha$.

GRAPHICAL REPRESENTATION OF CALCULATIONS

Fig. 19 shows the result of these calculations graphically, the upper set of curves being for the antenna in the air with 26-deg. distortion and for the antenna on the ground with zero distortion. The lower curve shows the airplane antenna characteristic.

Fig. 20 shows observations made in 1921, in which the distortion or shift at various altitudes was obtained, the diagram on the left being from observed data, while the one on the right was obtained from the theoretical formula. The dotted line in the figure on the left is the center line of the theoretical diagram. The close check is therefore obvious.

Fig. 21 shows a test flight in which both the minimum and the maximum equisignals were studied closely. The observed shift and calculated shift for the height flown check within a fraction of a mile, while the width of the equisignal zone was observed to be in very close accord with the width estimated from a distinguishable ratio of signal of 1.1 to 1.0. In each test, the accuracy of determining the equisignal zone was within 30 min.

Fig. 22 shows a most interesting flight. This flight

(*Concluded on page 227*)

TABLE 2—SIGNAL INTENSITY FOR HEAD-ON FLIGHT

ϕ	$\sin\beta\cos\alpha\sin\phi$	$\cos\beta\cos\alpha$	Signal Intensity
0	0.161	0.336	0.175
30	0.139	0.336	0.197
60	0.080	0.336	0.256
90	0.000	0.336	0.336
120	—0.080	0.336	0.416
150	—0.139	0.336	0.475
180	—0.161	0.336	0.497

TABLE 1—DETERMINATION OF RELATIVE FIELD INTENSITY ALONG AIRPLANE ANTENNA DUE TO LOOP TRANSMITTER

Θ	$\cos\Theta$	$\sin\Theta$	$\cos\beta\sin\alpha\cos\Theta$[a]	$\sin\beta\cos\alpha\sin\Theta$[b]	$\cos\beta\sin\alpha\cos\Theta + \sin\beta\cos\alpha\sin\Theta$
0	1.000	0.000	0.336	0.000	0.336
10	0.985	0.174	0.330	0.028	0.358
20	0.940	0.342	0.316	0.055	0.371
30	0.866	0.500	0.291	0.080	0.371
40	0.766	0.643	0.257	0.104	0.361
50	0.643	0.766	0.216	0.123	0.339
60	0.500	0.866	0.168	0.139	0.307
70	0.342	0.940	0.115	0.151	0.266
80	0.174	0.985	0.058	0.159	0.217
90	0.000	1.000	0.000	0.161	0.161
100	—0.174	0.985	—0.058	0.159	0.101
110	—0.342	0.940	—0.115	0.151	0.036
120	—0.500	0.866	—0.168	0.139	—0.029
130	—0.643	0.766	—0.216	0.123	—0.093
140	—0.766	0.643	—0.257	0.104	—0.153
150	—0.866	0.500	—0.291	0.080	—0.211
160	—0.940	0.342	—0.316	0.055	—0.261
170	—0.985	0.174	—0.330	0.028	—0.302
180	—1.000	0.000	—0.336	0.000	—0.336

[a] For conditions assumed, $\alpha = 20$ deg. below horizontal and $\beta = 10$ deg., $\cos \beta \sin \alpha = 0.336$.
[b] For conditions assumed, $\sin \beta \cos \alpha = 0.161$.

Air-Cooled Engines in Naval Aircraft

By COMMANDER E. E. WILSON,[1] U. S. N.

AERONAUTIC MEETING PAPER *Illustrated with* CHARTS

ABSTRACT

THE purpose of the paper is to point out the basic policies which have resulted in the fostering of air-cooled-engine development by the Navy, and to indictate where the development has led. Two roles played by naval aviation are designated "air service" and "air force." The former term refers to the functions of naval aircraft which are contributory to the ships of the fleets, such as scouting and the control of gun-fire. The latter term refers to the functions which involve the use of aircraft as an integral and component part of the Navy's striking force, such as combat, bombing and torpedo launching.

Seven different types of aircraft are required by the Navy for its different purposes, these being airplanes for training, fighting, observation, scouting, torepdoing, bombing, and patrol use. Scouting, torpedoing, bombing and patrol functions have been combined into one type in the past, but any airplane which combines multiple functions must suffer in its performance of the individual functions and it is desirable to provide a specific type for each required function.

Subsequent to specifying the engines now used in the airplanes for training, for fighting and for observation and saying that water-cooled engines in the 200-hp. field have been definitely supplanted by the air-cooled type, the author passes to a recitation of pertinent features connected with airplane tests conducted by the Bureau of Aeronautics with air-cooled engines installed in high-speed aircraft suitable for fighting. He states that the air-cooled engine has entered the pursuit field definitely to challenge the water-cooled engine and then discusses supercharging with Roots-blower-type superchargers, following this with description regarding recent application of the air-cooled engine to the bombing and the torpedoing-airplane classes.

The statement that the tendency to increase power is not sound is analyzed, as well as the preference in the Navy's development for radial rather than in-line air-cooled engines. The Navy is rapidly obtaining a line of three air-cooled engines that will meet most of its requirements. The large air-cooled engines are now equipped with 2 to 1 reduction-gears and can be installed with geared or with direct drive in twin-engined patrol-airplanes. Thus, the Navy then has the entire range of its aircraft air-cooled.

Since the approval of the basic policy to make naval aviation an integral and component part of the fleet that must go to sea with the fleet, the outlining of the types of aircraft required and their general characteristics, all the Navy's engines for aircraft have been developed for a specific purpose and it now has water-cooled engines of from 200 to 800 hp. and air-cooled engines of from 200 to 500 hp., the service ratings of which are shown in a chart. The requirements are low weight per horsepower, high economy in fuel, maximum dependability, maximum durability, maximum ease in maintenance, minimum cost, and easy adaptability to quantity production. With these requirements in mind, the author estimates the progress that has been made in naval-aircraft development, considering fuel economy, cooling efficiency, powerplant economy, dependability, durability, maintenance, cost, and production.

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PERHAPS the most significant development in American aeronautics today is the advance of the air-cooled engine. It has been said that water-cooling an aircraft engine is scarcely more logical than air-cooling a marine engine. This may be an overstatement of the matter, but there is considerable truth in the assertion. Air-cooled engines are of primary interest in naval aviation for numerous reasons. It is the purpose of this paper to point out the basic policies which have resulted in the fostering of air-cooled-engine development by the Navy and to indicate where the development has led.

Naval aviation has two roles which can be classified under the headings of "air service" and "air force." By air service I refer to the functions of naval aircraft which are contributory to the ships of the fleets, such as scouting and the control of gun-fire. By air force I refer to the functions of naval aviation which involve the use of aircraft as an integral and component part of the Navy's striking force such as combat, bombing and torpedo launching. Manifestly, naval aviation must provide a mobile force capable of taking the sea and of keeping with the fleet. Naval aircraft are now being employed on battleships and light cruisers where they are used as seaplanes which are catapulted from the decks of the ships and, upon returning, land alongside to be hoisted aboard. Naval aircraft are also used on aircraft-carrying ships so that they can be employed as landplanes or as seaplanes, depending upon their mission.

Any man-of-war constitutes a compromise of maximum offensive and defensive strength on a given displacement. When aircraft are added to the equipment of surface ships they meet a definite limitation as to size, because of the limited stowage-space available, and as to weight, because of the difficulty of hoisting heavy weights onto vessels that are rolling and pitching in the open sea. There is also a limit to the weight which a catapult can handle. Even on such enormous vessels as our latest aircraft carriers, there is a limit to the size of aircraft which can be employed. Thus, in the matter of aircraft development, the Navy is confronted with very definite limitations as to size and weight of its aircraft and yet it must produce aircraft which are at least the equal in performance of the larger aircraft that can be based on shore.

POWERPLANT WEIGHTS COMPARED

In the development of naval aircraft, the weight per horsepower of the aircraft engine is manifestly of the greatest importance. This weight is important not only because of itself but also because, in any airplane, the weight of the powerplant is reflected back into the weight of the structure. The heavier the engine is for a given power, the greater the wing-area necessary to support it becomes and the greater the weight of the structure to withstand the loads. Carrying this thought a little farther, we find that the fuel-economy of an aircraft engine is of great importance. The lower the specific

fuel-consumption is, the less is the quantity of fuel required for a given range and the less is the tankage capacity required to contain the fuel. This reduction in fuel quantity and in tank weight is likewise reflected back into the structure.

A brief comparison of powerplant weights between water-cooled and air-cooled engines shows that the water-cooled powerplant is heavier than the air-cooled powerplant by the weight of the cooling-system. This averages roughly 0.6 lb. per hp. The elimination of this cooling-system constituted the first point of attack after we had reduced the weights of the bare engines to what looked like the minimum consistent with reasonable dependability and durability. Again, since a careful analysis of engine failures indicates that a high percentage of the trouble is due to faults of the plumbing system, that is, to the fuel, the oil and the water pipe-lines, it is obvious that the elimination of one of these pipe-lines results in the elimination of about one-third of our troubles. The air-cooled engine is attractive, then, not only from its low powerplant-weight per horsepower but also from its complete elimination of the troublesome water cooling-system.

Types of Aircraft Required

The Navy requires for its different purposes seven different types of aircraft, these being airplanes for training, fighting, observation, scouting, torpedoing, bombing, and patrol use. It is possible to combine the scouting, torpedoing, bombing, and patrol functions into one type and, in the interest of economy, this has been done in the past. It is obvious, however, that any airplane which combines multiple functions must suffer in its performance of the individual functions.

For the training airplanes a 200-hp. engine is required. This need is met by the Wright Whirlwind nine-cylinder static radial engine of approximately 790-cu. in. displacement. This engine, as Model J-1, was put into service in a relatively undeveloped stage in competition with the Wright E-4 engine, which was the highest development of the Hispano type. In spite of the defects of the early models this type of engine, because of its superior performance, has replaced the Hispano engine definitely. The engine has now advanced to become Model J-5, and has been so reliable and so successful that it recently has come into use widely in commercial aviation. Water-cooled engines in the 200-hp. field have been definitely supplanted.

In the fighter and the observation classes, we have been using the 200-hp. engine pending the development of an engine of much greater power on a small increase in weight. This engine is now available in the Pratt & Whitney Wasp. The engine develops twice the power of the Whirlwind engine on about 70 per cent, increased displacement and 30 per cent increase in weight. The engine has passed all its dynamometer tests with unusual success. It is now being thoroughly flight-tested in high-speed fighting-aircraft, and is challenging the supremacy of the water-cooled engine in this field.

Water-cooled-engine proponents point to the large frontal area of the air-cooled engine as a definite bar to its use in fighters. It is manifestly unfair to compare engines on the basis of their bare frontal-areas, just as it is unfair to compare air-cooled and water-cooled engines on the basis of their dry weights. When an air-cooled engine is installed in an airplane, it is found that the engine can be cowled so that the cylinder-heads only are presented as drag-areas. Every fuselage must have sufficient cross-section to accommodate a pilot. In other words, we must take into consideration the masking effect of the fuselage in considering the drag-area of radial engines. We must take into consideration further the drag-area of the radiator required for the water-cooled engine. This factor is considerable. We must even go farther and consider the drag resulting from the additional wing-area required to support the cooling-system of a water-cooled engine. When we take all these factors into consideration we find that the air-cooled engine compares not unfavorably with the water-cooled engine, and we have not yet begun to develop means of streamlining air-cooled cylinder-heads.

Air-Cooled Engine Airplane-Tests

To demonstrate the possibilities of air-cooled engines in fighters, the Bureau of Aeronautics has been conducting airplane tests with air-cooled engines installed in high-speed aircraft. The Wright Apache airplane, a single-seat fighter equipped with the Pratt & Whitney Wasp engine, is a good example of what can be expected of an air-cooled engine installed in an airplane especially designed to accommodate it. This airplane shows speeds at least equal to those of the water-cooled fighters and a climb and a ceiling which are definitely superior.

As a further test, Pratt & Whitney Wasp engines have been installed in Curtiss and in Boeing fighters designed originally for the Curtiss D-12 water-cooled engine. In such makeshift installations we must accept some handicaps. Installation of the Wasp engine in the Curtiss fighter results in a reduction in weight of 240 lb., which corresponds exactly with the weight of the cooling-system of the original airplane; however, the engine must be installed farther ahead to maintain the balance, and this results in a slight increase in mounting weight. The reduction in powerplant weight reduces the landing-speed of the air-cooled fighter. If now we correct air-cooled-fighter performance up to the landing-speed of the water-cooled airplane, we find their high speeds about equal. When we take these different installations and reduce them all to the same common denominator, we find that the air-cooled fighter is almost exactly equal to the water-cooled machine of equal power and that it attains this performance on a 10 per cent reduction in gross weight.

In other words, the air-cooled engine has entered the pursuit field definitely to challenge the water-cooled engine, and this brings to mind the fact that our interest in racing has focused attention upon high speed at sea level as one of the important characteristics of an airplane. Manifestly, what we are interested in, particularly as pertains to fighters, is performance at the fighting altitude rather than at sea level, and here the air-cooled engine should have a decided advantage. The later types incorporate a rotary distribution-system which gives some supercharging at sea level and tends to maintain the mean effective pressure with increase in crankshaft speed. Performance at altitude is the proper criterion in comparing fighting aircraft.

Supercharging

We have recently put into service a number of Roots-blower-type superchargers developed for the Navy by the National Advisory Committee for Aeronautics at Langley Field, Hampton, Va. They have proved definitely that this type of blower is mechanically satisfactory and that air-cooled engines supercharged to sea-level conditions to 28,000-ft. altitude need no alterations or accessories to permit supercharging to this altitude. The shape of the engine lends itself well to the installation of this type of supercharger. Air-cooled engines super-

charged to sea-level conditions at fighting altitudes should have superior performance at those altitudes.

Roots blowers have two distinct advantages over the turbo-supercharger: first, the temperature rise of the mixture is so small as to eliminate the necessity for intercoolers and, second, the blower utilizes power in proportion to the supercharging effect. When no supercharging is used, only the friction horsepower of the blower is absorbed. When full supercharging is used at the critical altitude, maximum power is absorbed. This is not true of the fan-type supercharger as ordinarily installed. This Roots-supercharger development is one of the most important in military aeronautics today, and its promise for the future is great.

In the bombing and the torpedoing-airplane classes, whether these be single-engine or twin-engine machines, the air-cooled engine is again extremely interesting. At present our latest single-engine bombers are equipped with Packard 3A-2500 engines developing about 725 hp. at 1800 r.p.m. The weight of the cooling-system is approximately 500 lb. Assuming 5-hr. range at full throttle as a scout with 0.55 lb. per b.hp-hr. specific fuel-consumption, 2000 lb. of fuel will be required. A redesigned airplane carrying the same useful load has the same range with a 500-hp. air-cooled engine using but 1350 lb. of fuel. In other words a 500-hp. air-cooled single-engine bomber can have the same performance as a 725-hp. water-cooled bomber. In fact, through simplification of the installation, it is possible to reduce the weight further and thus attain a better performance with the 500-hp. air-cooled engine than can be had with the large airplane with a 725-hp. water-cooled engine.

In the torpedoing and bombing type we have an excellent illustration of a progressive development. Our torpedoing airplanes were originally designed around a single Liberty engine because this was the only engine available. By the time the airplane had been made sufficiently rugged to meet the requirements of the operating squadrons, it had become so heavy as to be unsatisfactory. To overcome the difficulty, the Navy fostered the Wright Model-T engine which was installed in later airplanes of the type. When these airplanes were put into service they also had to be stiffened-up. Certain changes and additions were made as the model progressed, with the final result that even though the Wright T-3 engine had been expanded to develop 540 hp. at 1800 r.p.m., the airplane was underpowered. To meet this difficulty, the Packard 2A-2500 engine is being installed in later torpedoing-type airplanes, the increase in installation weight over that of the Wright T-3 machine being less than 100 lb. In spite of the fact that with the big Packard engine we gain normally 200 hp. on an increased weight of 100 lb., the airplane has kept growing and so rapidly as to have absorbed all the gains from the high-powered engine.

Tendency to Increase Power Not Sound

This tendency to increase power is not a sound one. Increased power calls for more fuel and more tankage for a given performance. This results in increased weight, and the net gain is small in proportion to the effort involved. The new design of airplane employing the 500-hp. air-cooled engine promises better performance than the old airplane with an 800-hp. engine. This is an excellent illustration of the application of air-cooled engines in naval aircraft. At the same time, however, it serves to point out one of the disturbing factors in the broader aeronautic picture.

There are three divisions of the gross weight of an airplane: first, the weight of the structure; second, the weight of the useful load; and third, the weight of the engine. In a laudable desire to increase the useful load, we have had to increase the weight of the structure to withstand the load. At the same time we have endeavored to make our aircraft perform multiple functions and be seaworthy as well as airworthy. We are requiring that they be able to withstand heavy seas. This has resulted in a corresponding increase in structural weight. Adding weight to increase strength is not all gain, for the very addition of the weight increases the loads. As a result, while the weight-horsepower ratio of our engines has been steadily improved, the flying qualities of our aircraft have not been improved.

Attention was focused on this point by Mr. Breguet, the French designer. He speaks with a certain amount of authority because he, himself, has gone to great lengths in reducing the weight of his products through improved design. There is no question but that our American designers can accomplish the same thing. They cannot accomplish it, however, so long as we insist on unreasonably high factors of safety in the air and the ability to withstand a gale on the water. There are two extremes in the matter. The one contemplates the design of an airplane for high performance in combat with low factors of safety. The other contemplates aircraft which will have long life and which will withstand all the stresses and strains to which they can possibly be subjected in the air or on the water. This extreme may result in an airplane of low performance which will have little military value.

The low weight per horsepower of our improved engines makes it possible for our aircraft to compare not unfavorably in performance with foreign aircraft of light weight and lower factors of safety. However, there is a limit to what we can do by pulling ourselves up by the boot straps. It certainly seems that the time has come when we must establish some intermediate ground which will give reasonable safety and reasonable durability without too great sacrifice in performance. The engine builders have reduced the weight per horsepower of the engines. The next step is to apply similar methods of experimentation and development to reduce the weight per square foot of the wing-structure. Unless we apply ourselves actively to this problem we will, in time of war, in spite of our superior engines, be shot out of the air by enemy aircraft which may have inferior engines but which are built primarily for brief air-combat rather than long life.

Radial and In-Line Engines

We are accustomed to think of air-cooled engines as radial engines and of water-cooled engines as in-line engines. There are such things however as water-cooled radial-engines and air-cooled in-line engines. In our Navy development we have preferred the radial to the in-line air-cooled engine for a number of reasons. The short compact radial engine makes possible superior visibility for deck landings and bomb dropping, which is a fundamental requirement for naval aircraft. By virtue of its compactness, the radial engine has superior weight-per-horsepower characteristics, other things being equal. The in-line air-cooled engine may permit higher crankshaft-speed but, for our particular purposes, the radial engine seems more suitable. To date, the argument between the radial engine and the in-line air-cooled engine is purely academic and it will not be solved until in-line air-cooled engines have been developed and an actual comparison made. Basically, it is important to remember

that compactness is a fundamental requirement for low weight. In general, a sphere constitutes the optimum form from this viewpoint. Our radial engines, even when fitted with superchargers, approach this sphere in general form, while the in-line engines approach the square prism. In sizes up to at least 600 hp. we prefer the radial engine.

It will be seen that, insofar as air-cooled engines are concerned, we are rapidly obtaining a line of three air-cooled engines which will meet most of our requirements. The large air-cooled engines are now equipped with 2 to 1 reduction-gears and can be installed with geared or with direct drive in twin-engine patrol-airplanes. We then have the entire range of our aircraft air-cooled.

In developing this line of engines, we have kept in mind the desirability of interchangeability of parts between the engine types. In the two sizes of Pratt & Whitney engines, the two rear-ends are interchangeable. The advantages of this feature from the viewpoint of maintenance and operation are evident. It is our desire to extend the plan even farther so that all three engines will be as nearly interchangeable as their size will permit.

Basic Policy for Naval Aircraft

At the close of the war, the Navy made a careful analysis of the requirements of naval aviation. Basically, it was agreed that naval aviation, which, during the war, had been confined to training and coastal patrol, must be made an integral and component part of the fleet and must go to sea with the fleet. The next step was to outline the types of aircraft required and their general characteristics. This was done and approved as a basic naval policy by the Secretary of the Navy in 1922. At the same time, the General Board outlined the numbers of aircraft and the strength of personnel required to operate them. With the formulation of the policy, intensive effort was devoted to its consummation. Manifestly, the airplanes required certain definite types of engine. Their development had to wait upon the development of the engines. Our engine policy has been dictated by the basic policy, and all our engines have been developed for a specific and definite purpose. As a result, we have water-cooled engines of from 200 to 800 hp. and air-cooled engines of from 200 to 500 hp. The service ratings of existing Navy aircraft-engines are shown in Fig. 1.

With a definite goal, the manner of attaining it became of importance. The Navy is essentially an engineering organization. A battleship is a complicated piece of machinery, and whether a naval officer be working with guns, torpedoes, radio, Diesel engines, electrical machinery, steam powerplant machinery, or what not, he is essentially an engineer. The officer upon whom the duty of developing the aircraft engines was thrust was such an excellent engineer that he appreciated at once the necessity for arriving at a development policy. Two courses were open. The one to organize within the Bureau of Aeronautics an engine design branch to whose designs engines could be built, the other to turn to the aircraft-engine industry for the design and development work. Admiral Moffett decided upon the second policy, which has proved unqualifiedly sound.

The Bureau of Aeronautics, therefore, has acted not as a design branch but more as an executive engineering establishment. It has advised the engine-building industry of its needs. For each type of aircraft, it has established a standard of its requirements. It has encouraged, financially and otherwise, the development of the aircraft-engine industry, first by fostering experimental development and second by following up a successful development with sufficient production orders to maintain a healthy situation. That portion of the industry which has met the Navy's requirements has been in continuing production at an economical rate and has become stabilized.

Engine Requirements

The Bureau of Aeronautics acts as a liaison between the operating squadrons of the fleet and the builders of the engines. It encourages criticisms on the part of the fleet of the machinery furnished. It has obtained intelligent recommendations from the fleet and has transferred them to the engine builder. As a result of this highly cooperative effort between the operating squadrons, the Bureau of Aeronautics and the aircraft-engine builders, we have today both air and water-cooled engines which are cheap when measured by any or all of the requirements for aircraft engines. These requirements are (*a*) low weight per horsepower, (*b*) high economy in fuel, (*c*) maximum dependability, (*d*) maximum durability, (*e*) maximum ease in maintenance, (*f*) minimum cost, and (*g*) easy adaptability to quantity production.

In carrying on this development the Navy has endeavored to meet all these requirements, to balance them one against the other and to assist in the establishment in this Country of a sound engine-industry which will forever avoid the unfortunate situation which confronted us at the time of the entrance of the United States into the War. It will be remembered that we had no satisfactory aircraft-engine type or industry. Two courses were open, one to adopt bodily a foreign type of engine and build it and the other to bring through a new design. Either task was a colossal one. Both procedures were adopted. The French Hispano engine was brought over and placed in quantity production. The American Liberty engine was designed, developed and placed in quantity production. The rapidity with which both of these procedures were carried through is one of the outstanding achievements of engineering history, and yet the time required would have been fatal under many circumstances. Of the two methods, that of attempting to adapt a foreign design to American production methods proved more difficult. It is our purpose never again to be confronted with this difficulty if it can be avoided. The fact that four large companies are building aircraft engines in this Country and that one of them, the Packard Motor Car Co., is an extensive builder of automobiles whose entire resources could be used in time of emergency, indicates how far we have gone in this purpose.

Estimation of Progress Made

Considering now the requirements already listed and measuring them, we can ascertain what the progress has been. Taking first low weight per horsepower and making our comparison on the basis of total powerplant-weight, we see from Fig. 2 that we have gone from the Wright E-4 engine at about 4 lb. per hp. to the Wright J-5 engine at about 2½ lb. per hp. In the 400-hp. field we have gone from the Liberty engine at about 3 lb. per hp. to the Pratt & Whitney Wasp engine at less than 2 lb. per hp. These results are based on normal and not on over-speed ratings. They constitute a measure of the improvement from this angle.

It has been pointed out before that economy is important, primarily because of the reduction in weight of

fuel required. In a given type of engine, other things being equal, economy is a function of the compression-ratio which can be employed. This in turn is a function of the fuel available, and the fuel must be available for naval aircraft all over the world. Fuel limitations have kept us down to an average compression-ratio of 5.3 since we have been reluctant to use in distant service either the benzol-gasoline blends or gasoline treated with ethyl fluid.

We have employed ethyl fluid very extensively in the aircraft squadrons scouting fleet to meet a special condition, but we have endeavored to avoid anything except domestic aviation-gasoline for general service. In comparing our engines with foreign engines which have been employing high compression-ratios and special fuels in service types, we must take this into consideration. Even with our self-appointed fuel-limitations, our engines compare favorably in power and in economy with foreign engines utilizing special fuels.

Older types of air-cooled engine suffered somewhat in comparison with water-cooled engines in economy. Our cylinder designs were so faulty as to require over-rich mixtures to prevent detonation and preignition in high-powered engines. In the Model J-5 engine and in the Pratt & Whitney Wasp engine, the cylinder design has been greatly improved so that air-cooled engines are now running at very much better economies than their competing water-cooled engines. Not only that, but they have proved themselves capable of running supercharged at sea level to brake mean effective pressures which our water-cooled engines have not been able to withstand, and they can also be supercharged at altitude without any added complications. In other words, we have now advanced in air-cooled-engine design to the point where our air-cooled cylinders are superior in cooling characteristics to our water-cooled cylinders.

Cooling Efficiency

It may be well to digress at this point to indicate how the foregoing situation transpired. In consideration of the design of aircraft engines we started out basically with the thought that, in an airplane, we start off with a definite quantity of heat in the fuel-tank, which, at the end of a flight, has been dissipated. That which went into useful work through the propeller was dissipated to

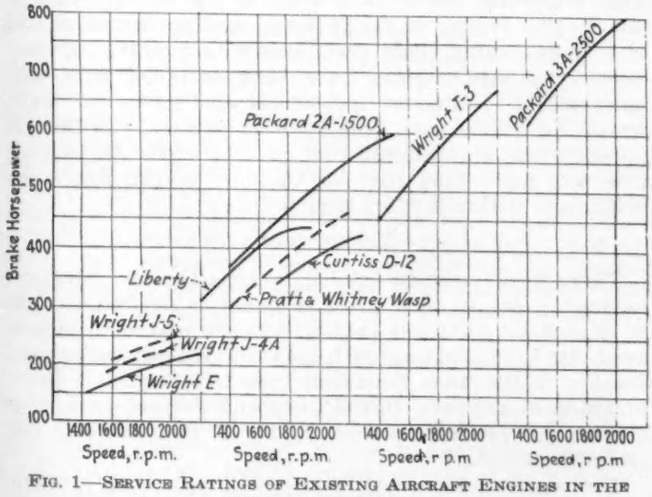


Fig. 1—Service Ratings of Existing Aircraft Engines in the United States Navy

The Basic Naval Policy Outlining the Types of Aircraft Required Was Approved in 1922. The Airplanes Required Certain Definite Types of Engine, But Their Development Had To Await the Development of the Engines. All the Engines Have Been Developed for a Specific Purpose. As a Result, the Navy Has Water-Cooled Engines of from 200 to 800 Hp. and Air-Cooled Engines of from 200 to 500 Hp.

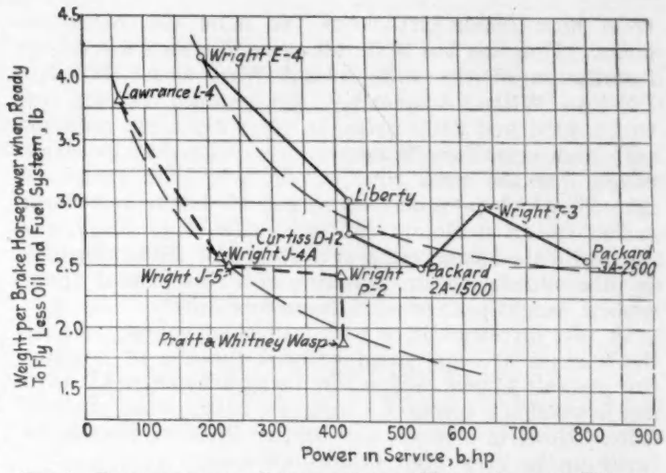


Fig. 2—Progress in the Development of Naval Aviation-Engines

Comparing First Low Weight Per Horsepower and Making the Comparison on the Basis of Total Powerplant-Weight, the Chart Shows That the Progress Has Been from the Wright E-4 Engine at About 4 Lb. Per Hp., to the Wright J-5 Engine at About 2½ Lb. Per Hp. In the 400-Hp. Field, the Progress Has Been from the Liberty Engine at About 3 Lb. Per Hp. to the Pratt & Whitney Engine at Less Than 2 Lb. Per Hp. These Figures Are Based on Normal and Not on Over-Speed Ratings

the atmosphere directly. That which was lost through the exhaust-stacks as heat rejected because of the cycle employed is likewise dissipated directly to the atmosphere. That which was transferred through the cylinders and pistons was also dissipated to the atmosphere, directly in the air-cooled engine and indirectly in the water-cooled engine.

The proportion of the heat rejected through the exhaust and through the cylinder-walls and pistons can be varied within narrow limits. Fundamentally, the design of an aircraft engine is a matter of heat-flow. Our inability to get rid of this heat easily has resulted in the development of special materials for valves, pistons, piston-rings, cylinder-heads, valve-seats, valve-guides, valve-springs, and all the other parts of the engine. We felt that if we could once solve the problem of heat-flow and get this rejected heat out to the atmosphere properly we would simplify all our mechanical problems greatly. We therefore took very great pains in the design of our air-cooled cylinders, making provision for every possible means of cooling. We even began to regulate the oil-supply to the pistons and to design these pistons to permit a ready transfer of heat to the lubricating-oil below the point where an oil-cooler would be required. We were careful not to carry this beyond that point. The final result was satisfactory beyond our fondest hopes. In the new air-cooled-cylinder design the cooling is so successful that the problems of overheated valves, burned pistons, stuck rings, and burned cylinder-heads have been simplified greatly. This is one of the outstanding achievements of air-cooled-engine development because it not only permits high power-output per cubic inch of displacement but also simplifies to a great degree the mechanical problems.

Powerplant Economy

In the question of powerplant economy, we must consider also the propeller efficiency. It is well known that propeller design is largely dictated by the speed of advance of the aircraft. A rough rule has been laid down that the propeller speed in revolutions should be on the order of 10 r.p.m. per m.p.h. In airplanes making a high speed of 125 m.p.h., the propeller speed should not be greatly in excess of 1250 r.p.m. without loss in economy. If now we want to employ the high powers resulting

from high crankshaft-speeds, we must use reduction-gears. This was the basic idea that dictated the engine installation of the water-cooled West Coast-Hawaiian PN-9's. With Packard 1A-1500 engines turning between 2200 and 2400 r.p.m. in level flight, we attained very high propeller-efficiency which resulted in increased range. At the same time we achieved high thrust on take-off, which permitted us to get off with a very large percentage of useful to full load. The final result was the world's seaplane endurance-record of 28 hr. 35 min. In other words, we are thinking now in terms of "powerplant weight per thrust horsepower-hour."

In fast airplanes it is permissible, of course, to turn the engines at high speed without the use of gearing. Our pursuit airplanes are now being so operated, utilizing crankshaft speeds as high as 2250 r.p.m. successfully. Now, in a steep dive at full throttle, the engine turns up to very high crankshaft-speeds of the order of 3000 or 3500 r.p.m. Our pursuit engines are perfectly capable of withstanding these high speeds.

Dependability

In the matter of dependability we have gone a long way. Dependability is not only a function of the design of the engine but of the skill of the operating personnel. We have emphasized the factor of "preventive engineering." In other words we have, by keeping records of the forced landings or delayed starts experienced by different pilots, pointed out the fact that a pilot, by checking over in advance of a flight all the details which may be a source of trouble, can largely prevent the occurrence of trouble during flight. At the same time we have improved and refined our accessories and engines to a very high degree. In fact, we have now reached the point where forced landings are more a matter of personnel than of material. The records of some of our operating squadrons are astonishing. A squadron using the early Model J-1 engine had more than 3000 hr. of flying without a forced landing. The number of delayed starts and forced landings is absurdly small where modern equipment is employed. Dependability has been tremendously increased through improved design, improved operation and through the elimination of the cooling-system.

Durability

Regarding durability, we have likewise gone a long way. As a result of long experience we have learned that Liberty engines installed in seaplanes where they are heavily loaded have an average life between overhauls of about 75 hr. We long ago established for ourselves a goal of 300 hr. in life between overhauls. This goal has been attained in new engine types and exceeded. By pointing out to operating units that life between overhauls is a function of the skill of the operating unit, we have focused attention on this important factor. As a result, we have numerous examples of engines which have gone well over 300 hr. One Wright Whirlwind engine has flown well over 400 hr. without major overhaul and is reported to be as good as new.

This factor of life between overhauls is of major importance not only because of the economy of operation but because, in a military campaign, long life between overhauls greatly increases the availability of the aircraft for service. Insofar as durability is concerned, we have improved at least 400 per cent. It is now more economical from the standpoint of current appropriations to buy a modern aircraft-engine than it is to recondition Liberty engines, whose life between overhauls is short and whose cost of overhaul is high; in other words, our development efforts, which have been somewhat expensive, are more than paying for themselves out of current funds. Our policy then of building new and improved engines rather than of using the Liberty engines on hand is sound not only from the standpoint of establishing the aircraft industry and improving the military characteristics of our airplanes but also from the standpoint of dollars and cents from current funds.

Maintenance

Concerning ease of maintenance, I have referred previously to the incorporation in the design of interchangeability of major parts. We have gone farther and have built our engines so as to permit quick overhaul at an air station. The radial air-cooled engines lend themselves singularly well from this viewpoint. For top overhaul, it is a simple matter to remove the cylinders and to grind the valves, leaving the engine in the airplane. On a recent occasion a Navy airplane arrived at the plant of the Wright Aeronautical Corporation for the substitution of J-4B cylinders in the J-4A engine. The engine was removed at a flying field some distance from the plant. It was transported by truck to the plant. It was completely torn down and new cylinders were installed. The engine was run-in for 5 hr. It was then given its dynamometer tests and again completely dismantled for inspection, reassembled and tested, reinstalled in the airplane, and flown away from the field, all within a period of 48 hr. and involving but 157 man-hr. in the whole process.

Recently, a Pratt & Whitney Wasp engine in an airplane at one of the flying fields was completely dismantled in a period of 2½ hr. This was not an attempt to establish a record, but it gives an indication of the ease of maintenance. Through precision shop-methods and standardization of parts, we have reduced the stock of parts required greatly and have simplified the maintenance problem.

Cost

As to cost, the radial engine is at a great advantage. The elimination of the cooling-system is no small item. In production, radial engines are less expensive to build because nearly all the parts are symmetrical or round, there are no large difficult parts to handle or large multiples, there are fewer parts than in the straight-line or the V-type engine of equal power and performance and the whole engine lends itself better to quantity production. Our late engines have been designed with this particularly in mind so that complicated parts and hand-finish operations have been reduced greatly. In fact, it appears that the reduced cost of the engine in production will more than pay for the cost of the whole development within a short period.

Production

There is no need to emphasize here the necessity for having an engine lend itself to quantity production. It is enough to point out that all modern aircraft engines are built in accordance with the American quantity-production policy, that hand-finish operations are reduced to the minimum and that all our engines can be placed in quantity production immediately if the necessity becomes apparent.

The air-cooled-engine development has been pushed along by the Navy in the face of considerable skepticism. It is a source, therefore, of the very greatest satisfaction to us to see Wright Whirlwind engines so extensively and successfully employed in commercial aviation If we have succeeded in developing an engine of use

commercially, we have at least contributed something to American aeronautics. I have been told that one Wright Whirling engine in commercial service flew some 600 hr. without any service whatever, and that when the company's service man appeared to substitute the improved J-4B cylinders the operator was at loss to understand the necessity for it. These engines are making for themselves a record of durability and dependability which will more than offset their comparatively high first-cost. A new training-engine development is on the way for the Navy in which first cost is to be reduced without sacrifice in dependability and durability. Once the cost is down to the point where quantity production can be had, commercial aviation and civil aviation will advance rapidly.

The rapid advances in engine development in this Country are due to close cooperation between engine users and engine builders. They represent today a high degree of engineering skill in manufacture as well as in operation. After all, the powerplant is the heart of the airplane. With our engines firmly established, we can look forward with great hope to the future.

THE ROTATING AND STATIONARY EQUISIGNAL BEACON

(*Concluded from p.* 220)

was begun in a dense fog that continued for about 20 miles. No difficulty was experienced by the pilot, who had only made one previous flight with the beacon. At the beginning of the flight he had a tendency to rely more on the compass and, for this reason, the flight was at first too far south, the compass being incorrect, as was later discovered. On emerging from the fog, no difficulty was experienced by the observer in immediately locating his position, as the plane was then very close to the imaginary equisignal line drawn on the map. The flight was continued and the city of Columbus, on which the bearing had been set, was reached less than ½ mile from the predetermined point known only to the observer. The equisignal shift in cross flight was very small, as a specially obtained wire and a streamline weight were in use, which allowed the antenna to hang at very nearly 80 deg. below the horizontal. The width of zone was less than 2 deg., while it was actually possible to determine that the true t (–) signal covered only 40 min. of bearing. The return flight was a most satisfactory demonstration, as the fog was so heavy over the last 20 miles that flight above 100 ft. from the ground was not possible, if the ground were to be seen at all. The map and compass now became useless, as both the pilot and the observer were forced to concentrate their attention on the ground and the space immediately ahead and to either side. It was simple for the pilot to keep his course regardless of a slight drift, and Wilbur Wright Field was reached without difficulty. During the flight, it was found to be entirely practicable to fly directly to the right or to the left side of the equisignal line; and it was realized that this would be a simple expedient to avoid a collision between airplanes flying over the same route but in opposite directions.

Numerous other flights of from 150 to 300 miles have been made over country with which the test personnel was unfamiliar; in all cases the flights were made with the greatest ease. One flight of about 300 miles was made to Monmouth, Ill., where a beacon, built by the Air Corps Radio Laboratory, at McCook Field, had been installed for the Air Mail Service. By the aid of this beacon, as well as that of the beacon in Dayton, a continuous flight was made without the use of any charts or other aids.

CONCERTED INITIATIVE IN EDUCATION

PROBLEMS of engineering colleges call for concerted action. When recapitulated, they make an imposing array. Among them are the problems of a better-balanced system of technical education, articulating curricula in engineering with those of other colleges, defining an acceptable function and scope for engineering colleges, carrying out an adequate program of educational guidance and publicity, a selective basis of admission, mutual cooperation with secondary schools, providing constructively for the personal and occupational adjustments of students and especially for a more satisfactory placement procedure, strengthening the status of engineering teachers, reasonable differentiation of curricula in accordance with technical and functional activities, relief from overcrowded programs, provision for more effective post-scholastic training and of more adequate but duly safe-guarded graduate work, the terms of award of professional degrees, giving greater flexibility and selectivity to our program, introducing a more distinctive professional tone to the upper years of the work, and more adequate emphasis on the economic basis and content of engineering. Limitations of time and not of material prevent this list from being largely extended.

The conclusion seems fairly inescapable that we have already gone about as far in developing a national system of engineering education as the initiative of individuals and of isolated institutions can be expected to carry us. Present investigation has revealed a strong mood for concerted action among colleges, provided their final autonomy is fully safeguarded. What is desired is not standardization but concerted initiative. That we are faced by many problems which the colleges alone, however effectively united, cannot solve and that the colleges, the engineering societies and the engineering industries are being drawn together by the recognition of mutual problems and interests seem equally plain. What is wanted is effective collaboration and not the dictation of any group to the others. Engineering education needs to be conceived and organized, not as an isolated form of educational activity, but as an integral part of the professional scheme and the industrial order.—W. E. Wickenden in a report to the Society for Promotion of Engineering Education.

SERVICE

WHY is it that in the year 1925 we exported $400,000,000 of automotive goods, $158,000,000 of chemicals, $78,000,000 of agricultural machinery, and $85,000,000 of electrical goods? Why is it that wherever lumber is cut American made saws and tools are used, that in every civilized country of the world our typewriters are to be found, and that specialty trade is increasing? It is because we are learning to give service. And in proportion as we give it so will we be able to compete abroad.—*Wall Street Journal.*

How I Fly at Night

By Wesley L. Smith[1]

Aeronautic Meeting Paper *Illustrated with* Chart and Photograph

ABSTRACT

THE experiences of the author in flying over an air-mail route are graphically portrayed. Although general practices hold for all routes, each route is said to present its own problems; special methods used in flying between any two points are not entirely effective in flying between any other two points.

Conditions along the New York City-Cleveland route are therefore described and such topics as lights and beacons, terminal fields, emergency landing-fields, and the various aids in locating the position of the airplane when the beacons are obscured, are discussed. Among these aids are the general appearance of cities and the direction of their main streets, large factories, blast-furnaces, amusement parks, lighted railroad trains, automobile headlights on main highways, railroad roundhouses, mountains, and rivers.

In night flying, much depends on the airplane, which must meet definite requirements. These include stability which is very important when flying by instruments, maneuverability, slow landing-speed, rapid climb, long cruising-range, and the capacity for carrying an ample supply of fuel.

Special nightflying equipment that is essential comprises navigation lights, headlights and parachute flares. When nothing is visible outside the ship, straight flying demands the use of certain instruments, which are grouped in the center of the instrument-board so that they all can be seen at once, namely, the compass, the turn indicator, the bank indicator, the alti-

[1] Pilot, Air Mail Service, New Brunswick, N. J.

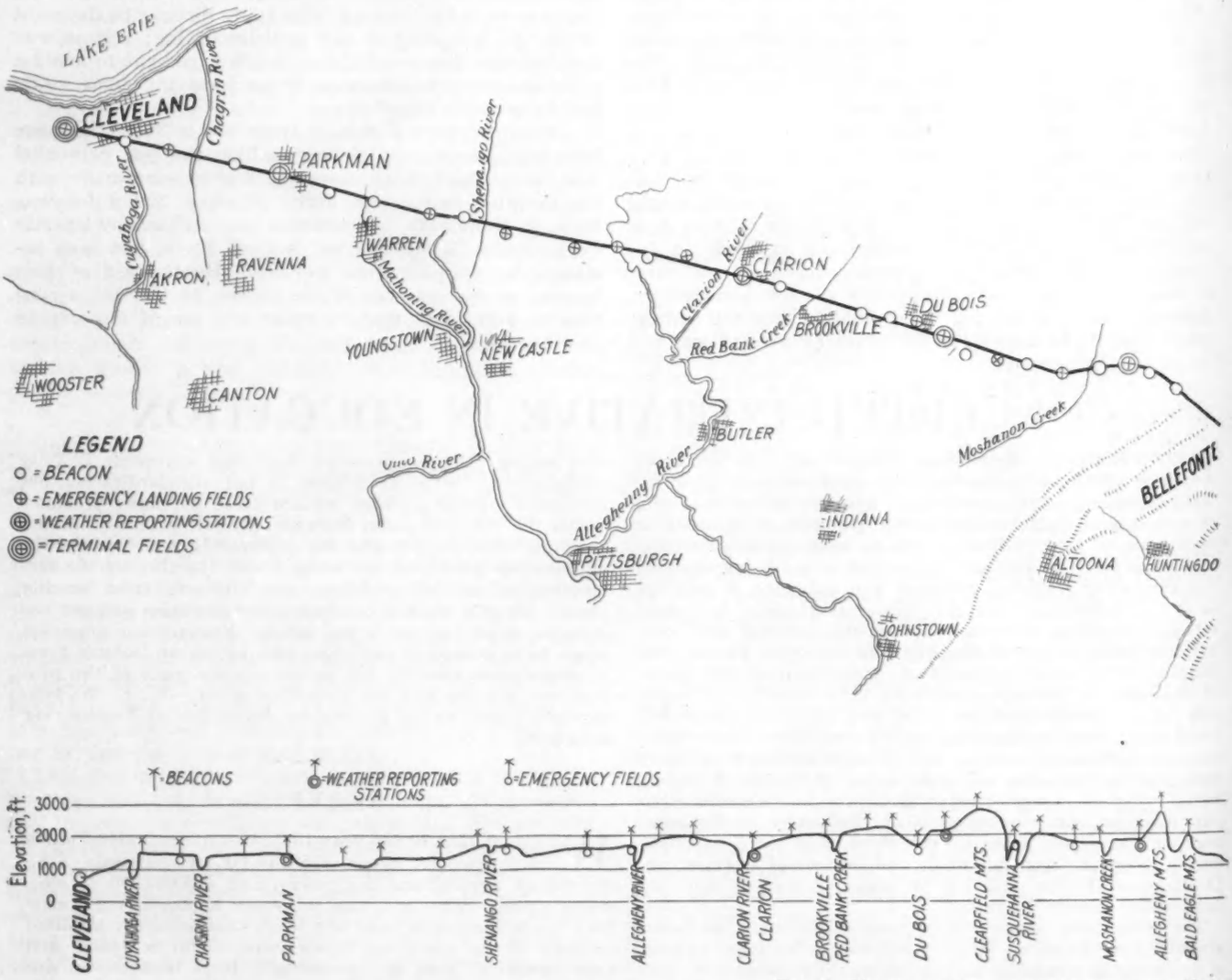


Fig. 1—Map and Profile of Route from New
On the Map the Clear Circles Represent Beacons; Those Having Crosses Are Emergency Fields; The Double Circles Are
Profile at the Bottom Shows the Topography of the Course with the Various

meter which also serves as a barometer, an air-speed indicator, and a tachometer. The function and method of operation of each of these instruments is explained.

Various means of overcoming the difficulties due to bad weather and the hazards that are most prevalent in each of the four seasons are outlined; the problems arising from fog are said to be the most important in the summertime, while the most serious of all is caused by the formation of ice upon the wires, struts and fabric of the airplane.

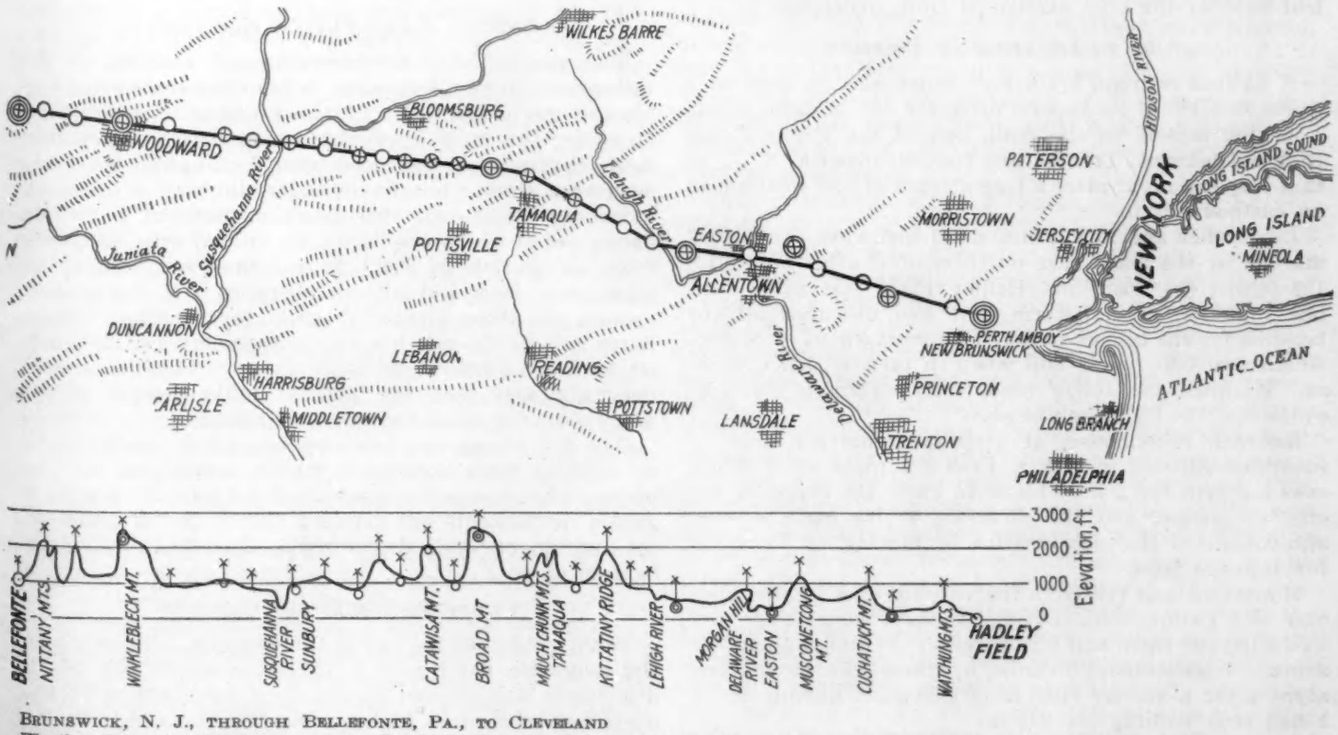
I SHOULD like to add to the title of my subject so that it shall read: How I Fly at Night between New York City and Cleveland. Every route presents its own problems for nightflying. Although general practices hold for them all, the special methods used on my night trail would not be entirely effective in flying at night between any other two points. There is no general scheme that fits every case any more than there is one drug that is a specific for all diseases. You will realize this better as I proceed.

So, the first thing to consider is the route. Fig. 1 is a large-scale map of the course and of the surrounding country. The heavy solid line is the course. The clear circles represent beacons, those having crosses are emergency fields, the double circles are weather-reporting stations and the triple circles are terminal fields where mechanics and supplies are available.

No complete contour-map is available. The lower part of Fig. 1 is a profile, to show the nature of the topography along the course. The heavy lines represent 1000-ft. elevations. In general, the country from New York City to Bellefonte, Pa., is a series of mountain ranges and valleys; from Bellefonte to Cleveland it rises abruptly to a plateau, with narrow river-gorges and low mountain-ridges and then slopes gradually down to Cleveland. The important mountain-ranges and the main roads along the way are roughly indicated to show their location.

Lights and beacons will be discussed by others[2] so I will mention only a few points concerning them. Beacons on emergency fields revolve in one direction; those on mountain tops revolve in the opposite direction. The latter are surmounted by red lights as an additional distinction. Each terminal field and emergency field is bounded by lights about 250 ft. apart. At the terminal fields, all near obstacles, such as telephone lines, houses and the like, are surmounted by red lights; the best approaches to the field are indicated by green boundary

[2] See p. 309.



BRUNSWICK, N. J., THROUGH BELLEFONTE, PA., TO CLEVELAND

Weather-Reporting Stations; and the Triple Circles Are Terminal Fields Where Mechanics and Supplies Are Available. The Beacons, Emergency Fields and Weather-Reporting Stations Indicated

markers. Each terminal field is equipped with a flood-light. For landing on emergency fields, the ship is equipped with two large landing-lights. The country is rough and most of the emergency fields of necessity are poor, so usually a parachute flare is dropped before landing.

Emergency Landing-Fields

Some emergency fields are better than others, only a few being safe to fly from at night, so we choose the best of these fields, when possible, for forced landings, if the conditions are such that the flight may be continued that night. As a result, some of these fields are used frequently, while others have never been used, but may be used at any time. The distance between beacons averages about 8 miles and that between fields, about 17 miles. Many persons have laughed at our seeming blindness in requiring beacons so close together. In fair weather, of course, they need not be so frequent; in fact, they are not necessary at all. I demonstrated this fact by making a flight from New York City to Cleveland in October, 1923, as a private venture, before the Air Mail service had even considered nightflying there. The beacons are necessary in thick weather, as we shall see later. The emergency fields are close together because the country is such that safe landings, other than those on fields, are not possible at night, except by parachute. No one yet has been obliged to use a parachute, but no one would think of flying across that country at night without one.

The beacons may be obscured by thick weather, so other guides are used. In nearly all the cities and towns along our course the streets are illuminated all night. A pilot who knows the general appearance of a city by daylight and the directions in which its main streets run may recognize it at night by its lighted street area. And those cities and towns are more numerous than are our beacons. Large factories, blast-furnaces and amusement parks are great aids. I definitely located myself by the blast-furnaces at Reading one night after flying over bad weather for 1 hr. eastbound from Bellefonte.

Aids to Location of Position

A lighted railroad train may sometimes be used as a guide at night if its general direction can be determined. I located myself on the main line of the Pennsylvania Railroad between Trenton and New Brunswick, N. J., in that way one night after a long stretch of bad weather on an eastbound trip.

In summer and in autumn, main highways are clearly marked by the many cars on them until after midnight. I followed the road into Hadley Field just after dark one night in a snowstorm that had obscured all the beacons for the last 50 miles. One must know, of course, which roads to follow and when to turn in order to do so. He must also follow roads where traffic is heavy in order that the lights can be seen.

Railroad roundhouses at division points are aids. I identified Altoona in that manner one night after flying over a storm for 2 hr. I had to know the shape of the city, of course, and the direction of its main streets, and completed the identification by picking up Tyrone a few minutes later.

Mountains and rivers in the vicinity of a lighted area may aid. Mountains outline themselves against any lights beyond them and rivers reflect the lights along the shore. I identified Pottsville by these two means one night after a stormy ride from Cleveland during which I had seen nothing for 2½ hr.

In general, the country north of the New York City-Cleveland course is rough and sparsely inhabited and has few lighted towns, while that to the south of it is the opposite; the general rule, therefore, is to fly a little south of the regular course when nothing has been visible for some time. An almost unbroken stretch of well-lighted factory cities extends from Pittsburgh to Cleveland that I have used several times to guide my course toward Cleveland. The anthracite country from Shamokin to Scranton forms a well-lighted semicircle that our course crosses almost at its center. This has been my aid to navigation in bad weather on more than one occasion.

Requirements of the Airplane

In order to do this sort of flying, much depends on the airplane, and very definite requirements must be met by it. First in order are the flying qualities, the most important of which is stability. In order to do much flying by instruments, we must have an airplane that is stable fore and aft, laterally and directionally. It must fly "hands off" whether flying level, climbing or descending in fairly rough weather. Flying by instruments is an intense physical and mental strain and the pilot needs as much relief as he can get from a stable plane.

The plane must be extremely maneuverable for getting into and out of poor emergency-fields that are surrounded by obstacles. It must have a slow landing-speed, because these fields are mostly small. It must have a rapid climb, to clear obstacles on a take-off and to climb quickly above clouds whose moisture may freeze on the ship and soon weigh it down to the ground. It must have a cruising-range that will carry us, non-stop, from New York City to Cleveland against a 30-mile head-wind, because the intervening country may be covered with storms that make safe landing impossible. In addition to this, fuel for an extra hour is needed to enable us to locate the course, if we have lost it on the way in bad weather. We have failed on many nights, because we lacked such a plane; but we believe that we now have one that will meet these requirements.

Special Night-Flying Equipment

The special night-flying equipment consists of the following: three navigation lights, one on each wing-tip and one on the tail, to enable pilots to see other ships en route; two large headlights for landing in emergency fields that are not equipped with flood-lights, these are somewhat similar to automobile headlights but are much more powerful; and two large magnesium parachute flares, one of which will light 1 sq. mile of area brilliantly from an altitude of 2000 ft. and thus will disclose an emergency field and all its obstacles. It burns long enough to allow plenty of time for landing. These flares are fairly reliable but occasionally fail to light, so two are carried by each plane. They are more generally used than the landing lights because of the many obstacles about the emergency fields.

Our five senses are not keen enough to enable us to fly straight when nothing is visible outside the ship, so we must have some instruments to aid us. All the navigation instruments are grouped closely in the center of the instrument-board shown in Fig. 2, so that they all can be seen at once.

Compensation of the Compass

In the center at the top is the compass. Inasmuch as the magnetic north-pole is in the neighborhood of 70 deg. north latitude and 97 deg. west longitude or to the northwest of Hudson Bay, the meridian on which an uncompensated compass would be correct passes over the

Atlantic Ocean off our coast. Compasses must be compensated to make them show the correct direction, and they can only be compensated in one locality. A compass compensated correctly at Cleveland is 11 deg. off at New York City. No roads or cities near New York City are laid out on north and south lines, whereas, in Ohio, they nearly all are so laid out. Compasses, consequently, are adjusted in Cleveland and the variations along the way to New York City must be known. The compasses must also be compensated to overcome the effects of the metal parts of the plane. As our course is not straight, allowance for that must also be made.

The earth's magnetic-field is parallel to the earth's surface only at the equator. In our latitude, it dips about 60 deg. and the compasses must be balanced accordingly. This makes every compass a pendulum and proper allowance must be made. Raising the nose of the ship suddenly causes the compass to swing to the north; lowering the nose suddenly causes it to swing to the south. In turning toward the north, the compass generally reads correctly, but turning toward the south causes it to swing past or farther than it should and to oscillate before coming to rest. So, sudden maneuvers must be avoided in navigation flying. During storms, when a compass is most needed, the plane is tossed about and does all the things just mentioned in spite of the pilot's best endeavors. Under the compass, therefore, is a turn indicator.

The Turn Indicator

The turn indicator records reactions on a spinning gyroscope, the pointer indicating the direction in which the ship is turning. In rough weather, the pilot tries to keep the pointer straight down and to hold to the average reading of the compass, the proper one for the course. The compass generally swings somewhat in a storm. The gyroscope in this instrument is operated by suction from a pitot tube mounted on one side between the exhaust-pipe of the engine and fuselage. One night last spring in the midst of a cloud that covered one of our high points I discovered that the instrument was not working. But the air was fairly smooth and I got through the bad stretch. At the next station, I discovered that the pitot tube was plugged with mud that had entered it on the last take-off. The mud had been thrown from the wheels to the propeller and from there into the pitot tube. I always observe the instrument now, after a take-off from a muddy field, to make sure that it is operating properly. The turn indicator will show the turn for a second to one side, if a bump drops that wing, so quick movements must be disregarded in rough storms.

Under the turn indicator is the bank indicator, which consists of a steel ball in a slightly larger curved glass-tube filled with alcohol, to dampen the vibrations. The steel ball remains in the center during level flight or while making a perfect turn that is properly banked. Any deviation from the center shows a low wing. If a turn is being made and the ball follows the pointer, the plane is overbanked and a side-slip results; if the ball goes in the opposite direction, the plane is underbanked and a skid results.

Many times my senses tell me one thing and the instruments tell me another, the peculiar feature being that the instruments are always right. When we first began to do this sort of flying, I had to try out all these things on a clear day to assure myself of this fact. The turn and the bank indicators must not be too sensitive or they will be useless when they are really needed in rough stormy weather.

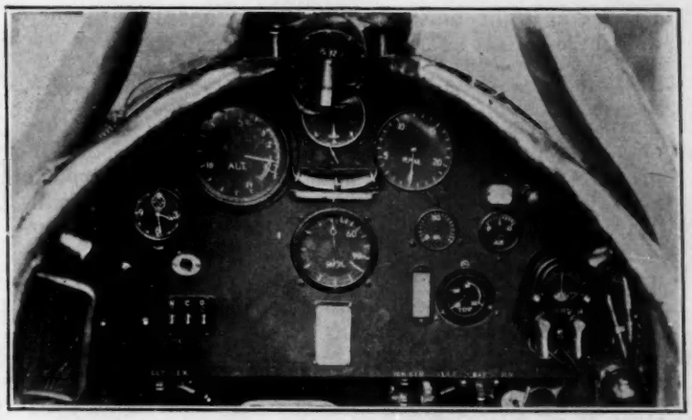


Fig. 2—View Showing Grouping of Instruments on the Instrument-Board

The Navigational Instruments Are Grouped Closely in the Center, So That They All Can Be Seen at Once. At the Top Is the Compass; Below It, the Turn Indicator; Below the Turn Indicator, the Bank Indicator; and Below That Is the Air-Speed Indicator, Which, Although Operated by Air-Pressure, Is Calibrated to Read in Miles per Hour. At the Left of the Bank Indicator Is the Altimeter, Which Also Serves as a Barometer; and at the Right of the Bank Indicator Is the Tachometer, Which Indicates the Speed at Which the Engine Is Turning and Also Serves as a Check on Climbs or Descents. On the Extreme Right Are the Engine Instruments, and at the Extreme Left, the Lighting Instruments and Switches and the Clock

The Altimeter

An altimeter, shown at the left of the bank indicator, consists of a sensitive diaphragm on one end of an enclosed cylinder. This diaphragm moves in and about as the air-pressure on the outside varies, its action being multiplied to move the hand on the dial. On the dial are two scales. The outer full one is calibrated in feet so that the hand will record changes of altitude to correspond to changes of air-pressure. But the air-pressure at any spot changes constantly due to the approach of storms, which are low-pressure areas, or to clear weather, which is a high-pressure area; consequently, these changes may cause the pointer to show a change of altitude of 1000 ft. while the airplane is remaining quietly in the hangar. The altitude scale, therefore, is movable and, before a trip is begun, is set so that the hand will point to the elevation of the starting-point above sea-level. Each of our fields is at a different elevation and, to take this into account, all elevations are referred to sea-level.

This instrument, since it measures changes of air-pressure, is also a barometer. The small inside scale is calibrated to read pressures corresponding to inches of mercury on a regular barometric scale and is set by comparing it with that of a standard barometer. The scale shows only the range from 29 to 31 in., which is the common variation of a barometer at sea-level. The barometric pressure may, and usually does, vary over a route, so that the altimeter, although set correctly at New York City, will show a wrong elevation upon landing at some other field where the barometric pressure is different. So we have barometers at New York City, Bellefonte and Cleveland, and the reading at the next station is obtained before beginning a trip. For sake of simplicity, these barometers are all corrected to give the reading as it would be at sea-level. The movable altitude-scale is then turned until its zero is opposite the barometer reading of the field toward which the airplane is traveling; when that field is reached, the altimeter will show the correct elevation upon landing. The altimeter, being correct for that area, then tells me how high to fly to clear all mountain peaks nearby, as they cannot

be seen at night, unless they are surmounted by beacons, and these cannot be seen in bad weather.

Air-Speed Indicator

An air-speed indicator is operated by a pitot tube on a wing strut outside the propeller wash. The air-pressure varies with the speed at which the airplane is traveling through the air, so the instrument is calibrated to read in miles per hour. Knowing the cruising-speed of the airplane, any climb or descent is indicated first by this instrument and then by a change of the altimeter. By its use, the airplane may be kept within safe climbing and descending speeds and may also be kept level fore and aft. This instrument is also useful in detecting the formation of ice. If the tachometer shows no variation but the air-speed apparently drops, ice is forming in the throat of the pitot tube and will shortly put it out of commission.

The tachometer, indicating the speed at which the engine turns, may also be used to check climbs or descents. With a fixed throttle, the engine slows down in climbing and speeds up in descending.

To the right of the instrument-board are the engine instruments and, to the left, the lighting instruments and switches. It is necessary to look at them only occasionally, so they are located at the sides. The clock is important in bad-weather flying because, when nothing is visible, one must fly by time, to know when it is safe to come down out of the clouds to look for beacons, or other land-marks, without being in danger of striking mountain tops. This requires an accurate estimate of the direction and velocity of the wind at the altitude flown and is possible only after several years of experience on one particular route. I can now make many trips in this way that would have been impossible for me 7 years ago, when I began Air Mail flying.

The instruments are all "radiolited." Other lights for the instrument-board are controlled by a rheostat. When there is much light outside, as in a thunder-storm, with a full moon or in flying over a well-lighted city, bright light is needed on the instruments. On the other hand, on a dark stormy night, when the beacons are barely visible and all is black outside, radiolite is sufficient. Other conditions vary between these two extremes so that rheostat control is needed. With these instruments we can fly "through Hell and hurricane" but, of course, cannot correct for drift or cannot land on fields that we cannot see.

The Weather

Our greatest problem, of course, is bad weather. If the weather were always clear, we should need neither beacons along the course, nor navigating instruments in the ship. There are many different kinds of bad weather, so I shall try to describe how we meet them all.

Let us first consider weather in general. If you watch for several days the successive weather maps published by the Weather Bureau, you will observe that the storm, or low-pressure, areas and the clear, or high-pressure, areas follow each other in succession across the Country from west to east. Each of these areas usually covers a region about 400 miles square at any one time and usually requires about 4 days to cross the continent. A storm in Cleveland one night usually moves to New York City by the next night; and, likewise, the clear waves, which are cold waves in winter and hot waves in summer. The surface winds blow toward storm or low-pressure areas, so we have east winds when a storm is approaching and west winds after it has passed.

The Weather Bureau gets reports at 8 o'clock every morning and from them prepares the familiar synoptic weather-maps that are issued before night. From our own weather-reporting stations, we get reports showing the type of weather, ceiling, visibility, wind direction and velocity, temperature, and barometric pressure. By type of weather is meant clear, overcast, broken clouds, rain, snow, and the like. The ceiling is the height of the clouds, if any, and is measured by projecting a spotlight at an angle of 45 deg. By pacing the distance from the light to the point directly under which the beam hits the clouds, the height of the clouds is obtained. The visibility is indicated by the number of beacons visible in each direction.

Speed and Direction of Storms

From our own weather-reports, we know where the weather is bad; from the Weather Bureau's maps, we estimate how fast the storms are moving and their approximate direction. The direction is always easterly but may be toward the northeast or southeast. From these reports we can almost always tell whether the next station will be visible when we arrive; if so, the flight is begun. If the weather becomes impossible at the next station while the airplane is en route, a couple of railroad fuses on an emergency field will bring the pilot down there.

When we had been doing nightflying for only a few months and had not begun to get weather-maps regularly, I left New York City one night with good weather-reports clear through to Cleveland. But a storm moving up from the southwest covered Bellefonte before I reached it. I had to turn back at Woodward and landed at Sunbury where we have a good field. If I had had sufficient fuel and had studied the weather-map, I could have flown through the storm to Cleveland, which was west of the path of the storm.

Let us now consider the four seasons and the weather hazards that each produces. The easiest season for us is summer, which often brings the common rainstorm. Rain itself is no barrier to visibility but is usually accompanied by fog and low clouds that hover about 200 ft. above flat country, envelop all mountains and high ground and force us to fly through or over them. Their upper side ranges in height from 5000 to 10,000 ft. Winds are generally from the west at these altitudes and airplanes up there lose speed. If the destination is reported as having favorable weather, the flight is begun. If westbound, flying at an elevation of about 3000 ft. clears all mountains; if eastbound, flying above the clouds will obtain aid from any favoring winds that there may be. It is easier to climb up through the clouds and fly in the clear, but this cannot be done while flying west, because of head winds, and loss of plane speed will not allow the pilot to reach his destination on his gasoline supply.

In summer, thunder-storms are usually local and very rough for flying. Fifteen minutes is usually sufficient to pass through one, though I did have a half-hour of excitement and hard work one night recently. The clouds in these storms are usually high, the rain is so heavy that there is no visibility and the lightning is very blinding at night.

Fog the Most Important Summer Problem

Our most important summer problem is fog. It plagues us along the coast and fills up the valleys inland, so that only one or two emergency fields may be available, namely, those which are located on high spots for

that purpose. Ground fog possibilities begin at dusk and increase rapidly, so that daybreak is the worst time. The sun usually clears it up by 10 o'clock in the morning. If the fog is thin, not more than 1000 ft. thick, and if the night is dark, beacons and city lights will show through sufficiently to keep the pilot on his course. Mountain tops, of course, are generally clear and their beacons visible. But if a bright moon is shining down on the fog, nothing can be seen below it. I spent an anxious half-hour one night en route to Cleveland. I flew through a storm for 1 hr. and then came out over a ground fog with a full moon. When I had passed out of the fog, I finally found myself a few miles south of the course.

We can start, of course, in any fog and can land through it, if the boundary lights show through it. I did this one night at Bellefonte. The mountain near the field rose above it and I could see the boundary lights straight down but lost them when I went back for an approach. By watching the altimeter, I got low enough over one end of the field to land on the third attempt, although the visibility was less than 500 ft. This would have been impossible by daylight or even by moonlight.

It is common to have everything east of the Blue Ridge Mountains covered with fog. This sort of fog is usually 2000 ft. or more thick and nothing shows through it. In such a case, it is possible to fly west from but impossible to fly into New York City, though the fog occasionally chops off abruptly at the Watchung Mountains and leaves the New York City area clear

Problems of Autumn and Winter

Autumn brings longer and more severe rainstorms and thicker fogs than summer, but they are not so frequent. Many times fog forms as the sun evaporates the frost at sunrise.

Winter brings snow. In snowstorms, the clouds are usually higher, touching only the topmost mountain peaks, but the visibility is poor. Usually straight down is all that one can see. I flew through such a storm for an hour just east of Cleveland one night, seeing only the towns and beacons as I passed over them. I was not in the clouds, for my navigation lights on the wing-tips did not flare into huge balls of light, as they do when flying through clouds. A severe blizzard over a landing-field would, of course, make landing there impossible. Snow on the ground is a great help in flying. Even on the darkest night, it is possible to see the ground, mountains and the like, when they are snow-covered. But, on the other hand, deep snow on landing-fields prevents their use. We do not often have enough snow on the ground all the way from New York City to Cleveland to use skis. So, the main fields are rolled to pack the snow and we can land and take off with the wheels. But, in the meantime, emergency fields are worse than useless, for the unlucky man who lands there must await a thaw or the coming of skis from a terminal field. Snow squalls of short duration are more frequent in winter than are thunder-storms in summer, but they are not bad for us.

Accumulation of Ice

The greatest of all our problems is ice. Until the Amundsen polar flight few had even heard of it, but we have been battling it unsuccessfully for several years. When the temperature ranges from the freezing-point down to about 10 deg. above zero fahr., moisture in the clouds will freeze on the airplane, first upon the wires, then upon the struts and the fabric, loading the airplane and increasing its resistance until it is forced down. When this happens the landing-speed is usually 20 or 30 m.p.h. higher than normal, due to the increased load. When the temperature is below plus 10 deg. fahr., the clouds are apparently composed of minute ice crystals that cannot and do not freeze on the ship.

If the clouds touch only the highest points, it is possible to fly just below them except at the high points, and the few minutes required to pass these points does not put on much ice. The other alternative is to fly above the clouds, climbing through them rapidly to avoid an excessive load of ice. This is usual eastbound, but can seldom be done westbound because of the prevailing west wind and the loss of speed by the airplane when aloft. As a result eastbound trips, under those conditions, are more likely to be completed than are westbound trips.

The ice coats the wires to three times their usual size. It coats the propeller unevenly, thus unbalancing it, and the resulting vibration sometimes snaps wires on the wings before the ship becomes overloaded.

It is sometimes warmer above the clouds than in them. I have several times lost the ice above the clouds that I had gathered while climbing through them. The temperature usually drops 1 deg. for each 300 ft. of climb, so it is sometimes possible to stay below the freezing zone when the lower strata are warmer. This is more common in the spring and autumn when ground temperatures range around 40 deg. and we can just clear our high points below the freezing zone in the clouds.

In the winter we get little help from automobile headlights on the roads. They are not numerous then nor are any of the amusement parks lighted.

Engines Are Kept Running

When forced to land on an emergency field, on account of bad weather at the next terminal field, we do not stop the engines, in winter. It is too hard to drain and refill them with water and oil and to get started again. An engine may be idled several hours, using very little fuel and oil, and the flight resumed when the weather breaks. Engines are very hard to start when cold and the caretaker of an emergency field is not of enough assistance. When an engine must be stopped in winter, it is usually necessary to send two mechanics to the pilot's assistance to get it started again.

Spring brings snow squalls, much sleet that freezes on the planes causing many forced landings and much fog. Fog is caused by alternate thawing and freezing, each thaw generally producing a fog. This alternate thawing and freezing makes all the fields soft and much care must be exercised in landing, even on the terminal fields.

For cold-weather flying, we developed an exhaust-pipe heater that feeds a supply of fresh warm air into the cockpit. This does not allow us to discard heavy flying suits, but it keeps our hands and feet comfortable in severe weather.

You have probably begun to think that bad-weather flying is largely "by guess and by God"; and so it is, to a great extent. We beat the trains on speed but fall far short of them on regularity. If the terminal fields have fair weather, we can fly through anything between them, except ice-forming clouds. We need a beacon ray that will penetrate the storms and guide us to the fields in bad weather and we need communication between the field and the plane en route to warn us of changes in the weather. If anyone is slightly bored with life and craves a little excitement, let him hop into a plane some dark and stormy night and try to fly to Cleveland.

FLYING IN CANADA

PEOPLE demand that the methods of transportation they use shall be safe, reliable and economical. When these three points are met, the problem of aerial transportation will be solved. Further progress in all three directions depends on the aeronautical research worker and on the aircraft and engine designer, more than on any other factors. In no way can the development of aviation be assisted more surely than by encouraging their work and providing funds for its extension Aircraft with greater range of speed must be produced so that low stalling and landing-speed may be combined with a good cruising-speed. A greater proportion of their gross weight must be paying-load. Reliable engines that are easy to maintain in operation and using less fuel per horsepower, and cheaper, and, what is equally important, less dangerous forms of fuel, must be produced. Operational experience is necessary too, but this exists today in practically all civilized countries, while the provision of ground facilities, the perfection of wireless services as applied to the operation of air routes and the extension of meteorological services are all essential.

Between Jan. 1, 1920, and Dec. 31, 1925, approximately 34,000,000 miles was flown on the world's scheduled air-routes; 10,000,000 lb. of mail, 15,000,000 lb. of express matter and 250,000 passengers were carried. These air-lines almost without exception have been either state-operated or heavily subsidized. None of them has been self-supporting; but, with the growth of traffic and the development of more efficient aircraft, the deficit on their operation is yearly becoming less. The experience gained in their operation shows that under suitable conditions, air transport lines may be conducted with sufficient safety, regularity and speed to make them an important addition to the existing channels of communication throughout the world.

In Canada, flying has been used principally as an improved method of observation. Straight transportation work has been subsidiary to this, and has been undertaken only when other modern facilities were lacking. This development, peculiar to Canada, arose from natural conditions existing in that country after the Armistice. Foresters, surveyors and those charged with the administration and development of the outlying districts had watched the progressive growth, in capacity and efficiency, of aircraft during the war. They were fully alive to the possibilities of aircraft for increasing the efficiency of their services. Therefore, an immediate demand arose for aviation in these lines of work the moment men and machines were available to develop them. The importance of air mail and passenger services was not lost sight of, but inquiries had shown that the establishment of an organized system of air transport throughout the country would entail very large capital and operating charges, without holding out much promise for some years of any adequate returns. It was therefore decided to concentrate on those services for which an immediate need existed; in forestry and aerial surveying and in transportation to the remoter parts of the country; and leave, for the time being, the development of air routes to countries where the natural conditions were easier, the population and traffic denser, and conditions altogether more favorable for experimental work.

It is of interest to note that there were no accidents to aircraft involving injury or death in Canada in the year 1925. Considering that 255,826 miles was flown, involving 3171 flights, or a total flying-time of 4091 hr., this record is remarkable. The Royal Canadian Air Force is to be congratulated on its excellent showing.—From Report on Civil Aviation for the year 1925, published by the Department of National Defense, Dominion of Canada.

ROAD-LOCATION ENGINEERING

TO be a good road-locating engineer a man should have had some experience in railroad work in positions of responsibility. The lessons learned in the railroad work will teach him the value of exactness. However, that experience is becoming harder to get as the railroads are not building many new lines, at present.

Good uptodate books on the subject of highway location are lacking. Probably the best books on this subject are the instruction books published by the various State Highway Departments. I have had many of them. Each attacks the problem from the angle of its particular State. Together they make a very good set of instructions.

All of this literature will be of considerable help to a man but he will have to learn most of his lessons in the actual work. He must be born with some very necessary qualifications, for I doubt if he can acquire them.

To make a successful locator a man must have a very vivid imagination. He must be able to see the new road as he walks over the country he is exploring. How will it fit this slope, how will it cross that stream, how are the swamps and hills to be avoided, are only three little questions of many for which he must find the answer.

He must have a highly developed sense of direction and an exceedingly good memory for geographical locations. He must have a sort of sixth sense to keep all the things seen on his exploring trips properly correlated. He must be a student of physical geography, of geology, of petrology, and in the glaciated parts of the Country a student of glacial geology. Also, he should be able to name the various trees met with and know what variety of soil is their customary habitat.

If highway engineering is to be of value, it must be thorough. Any new locations, or failures to make the needed new locations, will often fix the locations of roads for many generations to come. No hesitation should be felt in spending whatever is needed even if it seems out of all proportion to the cost of the actual construction work to be performed within a year or so. Government programs carry out this principle and they are often criticized for the high engineering cost but looking into the future is well worthwhile. The engineering program must be a complete, well-considered plan; otherwise it might just as well be discarded entirely—H. L. Brightman of the Michigan Highway Department in *Roads and Streets*.

ENTRANCE OF GRADUATES INTO ACTIVE LIFE

THE period of mal-adjustment marking the entrance of graduates to active life is possibly the natural result of an educational scheme that aims to fit everybody to get to the top and to fit nobody to be efficient in minor responsibilities and ends in an undignified scramble after the stars. Lengthening the required academic program to 5 years or more would probably make the matter worse. If we are able to find a way out, we shall probably have to seek it in company with the employers, through more cooperative work, better organized summer work, a saner placement system, and a more definite program and goal of further education to set before the graduate.—W. E. Wickenden, in a report to the Society for the Promotion of Engineering Education.

Some Freight-Handling Problems of New York City

By ELIHU CHURCH[1]

METROPOLITAN SECTION PAPER

ABSTRACT

THE highlights of the traffic situation in and about New York City are described, the problems raised by the rapid increase in number of both motor trucks and passenger cars are discussed and the remedies proposed by the Port of New York Authority for relieving traffic congestion are explained.

As railroad traffic is reaching the saturation-point, so is motor-truck traffic. An increase in the output of motor trucks from 411 in 1904 to more than 317,000 in 1924 has raised problems and caused congestion far beyond the vision of those who planned the facilities for operating the transportation equipment.

Because of inability to operate efficiently in the traffic jams around the railroad and pier terminals, motor trucks are being replaced by horse-drawn vehicles; in many instances the incidental costs of shipping goods are said to be from 10 to 16 times the amount paid to the railroad for the line haul. Numerous examples are given of the excessive cost of handling freight at the terminals as compared with that of line haul and reasons are cited for the failure of the motor truck to render a full measure of service. These include (*a*) underloading, (*b*) necessity for traveling unnecessary distances because of poorly located freight-stations, (*c*) slow speed because of congestion, and (*d*) inability to operate full time. Among the remedies suggested are the use of union freight-stations, which would serve as clearing-houses, and some means of reducing the loading and unloading times of trucks. Delays caused by traffic tangles due to wry-necked corners, break-neck grades, and bottle-necked streets will eventually mean large bond issues for improvements.

Although railroad line-haul is the cheapest form of land transportation in the world, its cost is only about 10 per cent of the total cost of shipping freight; it is in the remaining 90 per cent that a saving by the use of motor trucks in long-distance hauling is effected.

Looking into the future, the author predicts separate highways for passenger cars and trucks, and trunk-line highways over which tractors will drag trains of trailers. These highways will be carefully laid out as to grades and the like, will be equipped with despatching and wrecking service and will have such facilities as telephones and lights. Although traffic would be carried around the cities, the extra distance thus required would be compensated for by the saving in time effected by doing so.

Inasmuch as the cost of trunk-line highways through thickly settled districts would be excessive and the money for constructing them could not be raised by taxation, the prediction is made that they will be privately built and operated as toll roads. For entrance into cities, structures for carrying the roads above and along railroad rights-of-way are suggested.

THE development of the automobile has resulted in motorizing the highways. What are some of the problems that this new vehicle has raised and how shall we try to solve them? This development is so very recent that it is rather hard to get the correct perspective on the whole situation. In 1904 the total output of motor trucks in the United States was only 411. Now it has passed well beyond the quarter-million mark. Personally, I think that the motor truck and the passenger car are destined to make a greater change in the transportation methods of the United States as compared with those of the railroads than the railroads made over those of the stage coach.

When railroading was just beginning, 60 or 70 years ago, the railroad men of that day had absolutely no idea of what was before them. I sometimes think that the railroad men of today have no very clear vision of what the next two or three decades hold in store. I am a young man; yet I have seen three Grand Central Stations at 42nd Street and Park Avenue, and the third has just about reached the saturation-point. Already they are talking of diverting traffic and creating new stations and other passenger facilities.

Just as railroad traffic is reaching points of saturation, so is motor-truck traffic. Increase in motor-truck growth has brought about the present congestion. The result is that motor trucks are actually crowding themselves off the streets. In some parts of every city in this Country motor-truck operators have practically drawn a dead-line around certain districts and have said, "We will not send a truck into that section. If we do, it will get tied up in a traffic jam and no one knows when we shall get it out."

HORSE-DRAWN VEHICLES AT TERMINALS

What is the result? I will tell you one result. Everyone thought the motor truck would displace the horse. I can take you down to West Street in New York City, where the heavy freight is handled to and from the railroad stations and the steamship piers and let you count the number of motor trucks and horses. What do you suppose you will find? You will find today that out of every 100 trucks handling heavy freight there, 73 are drawn by horses. The horse is coming back. Why? Because the cost of trucking is measured by time, not by distance. If you go to any truckman and say, "I want you to take some freight from my factory to the Erie Station," or, "Go to the Cunard Pier and get some freight and bring it up to my warehouse," before he quotes you a price he will figure, not whether he must travel 1 or 5 miles, but whether it will take him 1 or 5 hr.

It costs about $0.06 per min. to keep motor trucks on the streets. Chauffeurs' wages, garage charges, overhead expense, and the like all amount to $0.06 per min. That charge goes on whether the truck is doing active useful work or is standing still.

When I talk about horses' coming back to men who build motor trucks and especially those who sell them, they say, "Great Scott, don't we build trucks that will carry 5 tons, go 20 m.p.h. and work 8 hr. without getting tired?" I say, "Oh, yes, you build that kind of truck but, after you have built it and sold it, does the man who bought it ever get that service out of it?" Investigations in New York City show that the average load of

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a 5-ton truck is about 1½ tons, that its actual speed when moving, due to street congestion, is about 4 m.p.h., and that, because of the time taken up in loading and unloading, the truck will do well if it turns a wheel for 3 hr. of an 8-hr. shift.

A horse-drawn vehicle can do all those things with much less overhead. In other words, a facility has been created, a machine capable of infinitely better service than the conditions under which it is operated will allow to perform. The motor truck, where its development is retarded, is held back not by any weakness of its own but by the conditions under which it operates, for no service that the truck can render will be a bit better than the road over which it runs or the traffic conditions under which it operates.

Terminal versus Long-Distance Trucking

Let us split this subject up into terminal and long-distance trucking. As a matter of fact, almost all the cost of transportation is at the terminals. Line hauls on the railroad are very cheap. The principal cost is in getting the goods to and from the railroads. It begins long before the goods are shipped, when you begin to box, bale, crate, and waterproof them. I know of many instances in which the incidental costs of shipping are from 10 to 16 times the amount paid to the railroad for hauling the goods, that is, the line haul.

I know of some goods brought here recently from Europe that were landed at 46th Street and the Hudson River and were trucked up-town. It cost more to truck them those 4 miles than to bring them 3000 miles across the Atlantic Ocean, including the insurance.

I know of some powdered milk that was shipped to New York City from San Francisco; it was stored in a warehouse in Brooklyn, after having been trucked from the steamship pier. For some reason, the shipper decided to postpone an advertising campaign in the East because a sudden demand came for that milk on the Pacific coast. So they shipped it back. It was taken out of the warehouse, trucked to the pier and loaded on the ship. Those two truckings through congested streets, from the pier to the warehouse and from the warehouse back to the pier, absolutely ignoring the storage charges, cost more than sending the goods from New York City to San Francisco by way of the Panama Canal.

I know of a large wholesale-distributing firm that has a warehouse and distributing place in lower Manhattan. Three years ago they moved to Brooklyn, for Brooklyn streets are not so congested as Manhattan streets. They claim that in the first year $150,000 was saved in trucking charges alone. That shows what congestion means in dollars and cents. I have figured out that in New York City alone the loss is more than $500,000 a day.

The motor truck can help lower these costs if it is given a fair chance, but it is not getting a fair chance at present. A great many foolish restrictions are blocking it. But you cannot block the motor truck long; it is here to stay. What we ought to do is to make possible its increased use without its being a menace to the public.

Causes of Motor Trucks' Failure to Render Service

The failure of trucks to render the full measure of service of which they are capable falls under four main headings. In the first place, they are generally underloaded. I have told you that the average load of a 5-ton truck is about 1½ tons. Why are trucks underloaded? Take a man who is shipping freight from a warehouse or from a business establishment in New York City. He seldom sends all that freight over one railroad; on a average, he ships over three or four railroads each day. Can he put all the 5 tons on one truck and say to the chauffeur, "Go to this road and drop a couple of tons, then to that road and drop a ton, then to the third road and drop the rest?" The chauffeur will say, "Chief, when I get to that first road, I shall be lucky if I get a chance to unload the stuff this afternoon." What is the result? The man puts 2 tons on one truck that ought to carry 5, 1 ton on another truck that ought to carry 5, and often sends three or four trucks out partly loaded when one could have carried it all.

Trucks travel unnecessary distances because a great many freight-stations are badly located; they travel with considerable delay because of inadequate terminals and, because of street congestion, they travel at very slow speed. If truck builders want the operators to get full measure of service, they must see to it that conditions are improved so that the trucks can be operated where they can carry full loads, for the full time, at full speed, and over the shortest distances. Those are the four things we must aim at.

Increasing the Loads

How are we to increase the loads? The Port Authority has decided that one of the ways of doing it is by unified terminals. We have union passenger-stations. We must have union freight-stations. Then no matter over what road, or over how many different roads, goods may be shipped, all the freight will be sent to one union-station. When it gets there, it will be unloaded and sorted, some for one railroad, some for another and so on. The stations will act as clearing-houses for freight. They will be located in the districts in which the freight originates and to which the inbound freight is destined. New York City alone does the business of 10 ordinary cities. Suppose it were to be split up into 10 districts, each of which received and shipped approximately an equal volume of freight, and a union station was built in the center of each of these districts. The haulage distance would be lessened.

The next thing would be to cut down the loading and unloading times of the truck. The Port Authority recently kept a group of timers at one of the big railroad-pier stations for 1 week. Whenever a truck drove up, the men noted the time it arrived, how long it was in line before it had a chance to unload, the time required for unloading, and the quantity of freight unloaded.

We found that trucks were there 68 min. on an average. The time actually required for unloading the freight was 14 min. That means that each truck wasted 54 min. At $0.06 per min. that means $3.24 per load. The loads averaged only 2154 lb. In other words, the railroad could haul that 2154 lb. from New York City to Buffalo for what it costs to keep a truck waiting for 54 min. A little congestion on the west side of Manhattan Island was as expensive to the shipper as an additional line-haul of 400 miles. Freight-stations must have adequate tail-board capacity to accommodate the trucks using them.

Much has been written about some of the traffic tangles caused by wry-necked corners, break-neck grades, bottle-necked streets, and cross currents; and you have been told how they result in casualties, expensive trucking and large police budgets. Tax payers will soon be obliged to face some big bond issues for improvements.

Using Motor Trucks for Long Hauls

The other side of the picture is the long-distance trucking. Remember that, in the first place, motor trucks were

considered as merely replacing horses, and horses did not operate over a radius of more than 10 miles. But the horse is holding his own under the present terminal conditions because of the congestion, and the motor truck, instead of competing with the horse, is now competing with the railroad for long-haul business.

Outside of terminal work, the average haul of a motor truck is said to be about 50 miles. How does that happen? We all know that the railroad line-haul is the cheapest form of land transportation in the world. I have told you, however, that the cost of the line haul is only a very small part of the cost of making a shipment. In other words, the railroads get only about 10 cents of the transportation dollar. It is because the motor truck saves on the remaining 90 cents that the motor truck is getting the long-distance business.

A man in this district who had some motor trucks thought he would go into long-distance trucking. He felt that the territory about New York City had been pretty well combed over, so he went to the manager of the principal factory in a large town in Massachusetts, introduced himself and said, "I have come to arrange to carry your freight from your factory to your warehouse in New York City."

"Why," said the manager, "you cannot compete with the railroad on that long haul. It is perfectly ridiculous; you know how low the railroad rate is per ton-mile."

The truckman said, "Let us consider some other things. How much does it cost you to box your freight? How much does it cost you, after you have boxed it, to get it from the factory to the railroad station? How much does it cost in New York City to get it from the railroad station to your warehouse?" They figured those costs and found that they amounted to $11 a ton.

"Now," said the truckman, "I will carry 6 tons on each of my trips. That will make a saving on incidentals alone, if you patronize me, of $66 per trip." That more than offsets the difference in the costs of the line hauls of the motor truck and of the railroad.

Saving the Cost of Boxing

The vice-president of the Underwood Typewriter Co. the other day gave me a still better example. The company has a factory in Hartford, Conn., from which typewriters are shipped to New York City. They were formerly shipped by railroad. To ship a typewriter by railroad, it must be carefully boxed. The cost of lumber and of labor have gone up. It costs more than $1 per machine to pack a typewriter so that it can be sent by railroad. Now the company has a fleet of motor trucks that look like moving-vans. Each truck has 300 felt-lined compartments just the size of a typewriter. When a typewrtier is put in, it requires no packing. A truck backs up to the factory door in Hartford, a procession of men come out with typewriters in their arms and put the 300 typewriters into the 300 compartments. The back door of the van is closed, the truck arrives at New York City in a few hours and $300 per trip is saved in boxing alone. The railroad wonders why it has lost the business!

I can cite dozens of examples of that sort in which the motor truck is making good in the long-distance field. That traffic will make necessary some interesting changes in the highways. In the first place, you will find that it will soon be essential to separate passenger vehicles from freight vehicles on the highways. Anyone who has trailed along behind a heavy truck for 4 or 5 miles on a dusty road before having an opportunity to cut around it and who then finds himself behind another one realizes that passenger cars and freight vehicles do not belong on the same highway.

In the next place, we shall find that we shall need an entirely new type of highway. In order that you will not think I am referring to an ordinary road slightly widened and resurfaced, I shall talk about "motor trunk-line highways." We have trunk-line railroads. We must come to trunk-line highways. We shall have trunk belt-lines around the centers of congestion and special developments for bringing motor trucks to the water front.

Motor-Truck Operation during the War

I suppose the operation of motor trucks reached a greater development in Europe during the war than anywhere else. It was necessary to furnish the front with supplies by motor vehicles. The operation of the roads was carried on like that of a railroad. Trucks were dispatched in convoys as a train-dispatcher dispatches trains. The work was so well coordinated, a British officer told me, that when one of the main highways was so badly bombed that it could not be opened again for about 2 hr., it slowed down the unloading of ships at the base ports in France. If it was so badly bombed that it could not be opened for 4 hr., it slowed down the loading of ships in the ports on the English side of the Channel. If it was bombed so that it could not be opened for 7 or 8 hr., it would slow down the schedule of the manufacture of munitions in the factories in England.

These trunk-line roads will be laid out by men trained in railroad location and will be constructed with the same care as to grades and curves that is given to railroads. That may seem unnecessary and ridiculous. We all know that a motor truck has hill-climbing capacity, that when it comes to a hill, the chauffeur puts it into low gear and "steps on the gas" and the truck goes up the hill.

It is my opinion that within 10 years most of the long-distance trucking will be done with tractors and trailers, and then the grade of the highway will limit the number of trailers that a tractor can haul, just as the grade of the railroad limits the number of cars that a locomotive can haul. Do not think that these highway trains will be hard to manage. They will be controlled by air-brakes operated by the chauffeur of the tractor just as freight cars are controlled by air-brakes operated by the engineer in the cab of the locomotive.

The methods of their construction, the equipment of the roads and their operation are matters that require too much detail to be discussed here. You will find that the grade crossings on highways of that sort would be much more dangerous than grade crossings on an ordinary railroad because the traffic would be much more intense. I would rather cross the track of any railroad in the Country than a highway having 1000 vehicles per hr.

Facilities for Trunk-Line Operation

You will find that it will be necessary to furnish facilities, such as telephones and lights, along the road, that a wrecking service will be required and that trucks must be handled as intensively in this Country as they were in Europe during the war, because roads of indefinite width cannot be built continually. Roads are expensive and the greatest volume of traffic must be sent over a given road. The only way in which that can be done is by installing a dispatching service on the highways.

Service must accompany the facility, for a facility without service is practically useless. Traffic, when it

approaches cities, will be carried around them by belt-lines. Cities need their streets for their own domestic uses, for the butcher, the baker, and candlestick-maker. Take a city like Elizabeth or Newark; if 1000 foreign cars per hr. were sent through the streets, they would practically paralyze the use of the streets for local business.

Extra distance is occasioned by these belt-lines. It costs money to operate a truck over an extra distance. It might cost $0.25 per mile. But remember that it costs $0.06 per min. for every minute that a truck is held up while going through the city streets. If you can save 4 min. at $0.06 per min., you can afford to go an extra mile for $0.25. It is practically an even break. You must begin to consider distance in terms of time.

Development in Cities

When traffic gets into largely built-up districts the question will become one of dispersion rather than of concentration. A new development in cities will take place, too. You will find that with the distribution of electric power, home industries will grow up along the lines of the highways. You will find communities lining the trunk highway between New York City and Philadelphia on either side of the road clear through from one city to the other.

These roads will be very expensive to construct, but you cannot call on the ordinary taxpayer for any larger sum for highways than he is paying at present. I understand that in the State of New Jersey $1 out of every $5 taken from taxpayers is now spent for roads, roads that often are of very little use to the man who has paid for them but are sources of profit to forwarding companies operating clear across the State, from Philadelphia, let us say, to New York City.

The original highways in this Country were mostly private enterprises. A number of farmers cooperated, cleared the line, put up a toll-gate, and formed a company to operate that stretch of road, charging for the use of it. In that case, a man who used the road paid for the use of the facility in direct proportion to the amount of use he made of it.

When the railroads were first built, they were operated on this principle for a while. Then the Nation developed and the municipalities and the States took over the roads, did away with the toll-gate, and made them free. By that time, however, the railroads were doing all the long-distance hauling and the roads were merely means of local communication. A man seldom drove farther than from his farm to the nearest railroad-station. In fact, the roads were never used for long-distance hauling. Now the motor truck has come and the situation is changing.

We shall have need for these special roads, which will be maintained and operated under conditions of heavy traffic. You cannot get the money from the taxpayer to build these roads, yet the transportation business of the Country needs them. As the railroads will specialize more on long-haul shipments of bulk freight, as the savings in packing and crating and the advantages of door-to-door service of the motor truck develop, and as the motor truck handles more and more business up to distances of 100 miles, you will find an enormous demand for highways over which such trucks can operate.

Toll Roads

It will be worth a large amount of money to the operators of truck fleets to have such roads, money that they will gladly pay for the use of them; and soon you will find companies chartered just as the railroads were, except that the companies will be chartered to build highways, and they will have the right to charge a toll for the use of their roads. They will be built by private corporations for individual profit.

When the time that roads of that sort will save and the additional loads that can be carried are taken into consideration, the users of the roads will gladly pay for the facility. The volume of business that I see desiring to travel by highway in the near future will make the proposition very profitable.

THE DISCUSSION

J. F. Winchester[2]:—Mr. Church made the statement that the average 5-ton truck carries only a 1½-ton load. Does he refer to the Metropolitan district or to the average throughout the Country?

Elihu Church:—That refers simply to terminal conditions; when the trucks are on the highway making long-distance hauls, they are fully loaded.

C. W. Tomlinson[3]:—I should like to suggest to Mr. Church that he adopt the container system entirely for terminal work. When the container system is used in connection with motor trucks, railroad terminals can be established anywhere within 25 miles of a distant point. The freight can be loaded into the containers at the off-line station. If the hauling by truck to the off-line station is considered too hard, the freight can go directly on to the cars and be delivered within 5 miles of the off-line station. If a container is loaded at a plant in New York City and is destined to go through Philadelphia, or any other point, there will be no difficulty; one of the cars or any number of them can go through to its destination.

T. D. Pratt[4]:—I should like to call attention to a condition that existed in England in 1835, approximately 90 years ago. Steam buses were then operating on the highways and were proving successful economically. A law was passed that in front of every one of the steam automobiles must go a man riding a horse and carrying a red flag. The development of highway transportation by mechanical means was set back 80 years. At present any Interstate Commerce Commission regulation of an undeveloped industry may have a similar effect.

[2] M.S.A.E.—Supervisor of motor equipment, Standard Oil Co. of New Jersey, Baltimore.

[3] Consulting engineer, New York City.

[4] M.S.A.E.—General manager, Motor Truck Association of America, New York City.

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Progress in Aircraft-Engine Design

By Arthur Nutt[1]

Buffalo Section Paper *Illustrated with* Charts and Photographs

ABSTRACT

THE marked advance that has been made in the last 10 years in constructional details and in performance of airplane engines and in airplane performance is reviewed, beginning with the year 1916 when the Curtiss OX-5 eight-cylinder water-cooled engine was brought to its final stage of development. The author describes briefly each type of engine produced successively by the company he represents and tells of the changes that were made to improve the performance.

From the 8-cylinder V-type the constructors changed to the 6 and 12-cylinder water-cooled type and are now developing a 9-cylinder air-cooled radial engine that was built in 1925. An important field of usefulness is foreseen for the air-cooled engine. Up to 500 hp. the air-cooled engine weighs less per horsepower than the water-cooled engine when installed; from 500 to 1000 hp. the weight of the two types, installed, is about the same; and at powers of more than 1000 hp. the water-cooled engine begins to have the advantage in installed weight. In larger powers than 500 hp. the indications point to the V and X types of air-cooled engine as preferable to the radial type. An air-cooled Liberty-12 engine has been built successfully and tested by the engineering division of the Air Service at McCook Field, which has also developed the cylinder of the 400-hp. air-cooled Curtiss engine, in which the exhaust-valves are as well cooled as those in any water-cooled engine.

The problem in designing aircraft engines is to obtain the best relation of (*a*) weight, (*b*) frontal area, (*c*) cost, (*d*) bulk, (*e*) high performance, and (*f*) reliability; and all of these factors are involved with the proper arrangement of parts and the proper selection of materials. More than 40 different kinds of material are used in the modern engine, of which the more interesting are the light and unusual alloys, such as magnesium, aluminum-bronze, duralumin, and Y alloy. The characteristics of each of these that make it especially suitable for different parts of the engine are given. Fourteen different materials are used in one cylinder-block of the Curtiss 500-hp. engine, as follows: duralumin, magnesium, aluminum-bronze, nickel-chromium steel in two analyses, carbon-steel in two analyses, cast iron, brass, copper, cold-rolled steel, drill rod, chrome-vanadium steel, and silchrome steel.

Future development of the water-cooled aircraft engine probably will be the combination of reduction gearing from the crankshaft to the propeller with high engine-speed and supercharging. The gear-reduction problem has been solved and gears can now be made as reliable as the engine. Availability of the lighter alloys at reasonable cost, together with supercharging and gear reduction, should make possible the reduction of the engine weight to close to 1 lb. per hp. During the last 10 years the weight has been reduced from more than 4.00 lb. to less than 1.33 lb. per hp. The rotary inductor on the Curtiss 400-hp. air-cooled engine has made possible a fuel economy of less than 0.50 lb. of gasoline per hp-hr. at one-quarter throttle opening.

Airplane endurance, ceiling, range, and speed have improved together with engine performance. The endurance record for a non-pay-load machine now stands at 45 hr. 11 min. 59 sec., and was made in France in August, 1925. It seems likely that in 1928 an endurance of 26 hr. with a pay load of 500 lb. and of 20 hr. with a load of 2500 lb. will be possible. The no-load flying range is now 2728 miles and by 1928 should be 1900 miles with a useful load of 2500 lb. An altitude of 32,700 ft. was attained by a Curtiss triplane without supercharger in 1919 and it is predicted that 50,000 ft. will be reached with a supercharged engine in 1928. Pursuit airplanes have had 10,000 ft. added to their ceiling ability by the use of the supercharger, and from 7000 to 8000 ft. probably will be added in the next 3 years.

A racing-airplane speed of 266 m.p.h. was reached in this Country in 1923, and this was increased in France in 1925 to 278 m.p.h. The French, however, attain their records with airplanes having very high landing-speeds. By reducing the wing area of our racing airplanes to raise the landing speed from 75 m.p.h. to 100 m.p.h., we could increase the top speed to more than 290 m.p.h., but speed range is more desirable than mere high speed. The Schneider Cup for seaplanes was won at Baltimore in 1925 against England and Italy at the world's-record speed of 233.8 m.p.h. and the same Curtiss racer made 245.1 m.p.h. over a 3-km. (1.86-mile) course. Service pursuit-planes now fly at 175 m.p.h. as compared with 140 m.p.h. in 1920 and 125 m.p.h. in 1918.

A sharp increase in the brake mean effective pressure of aircraft engines from 1916 to 1919 was due principally to improvement in spark-plugs. The compression-ratio is limited at present by the detonation characteristics of the available fuel; the highest ratio that is regarded as advisable when using domestic aviation-gasoline is 5.5 to 1.0. No radical increase in engine-power is to be expected except as the result of raising the normal engine-speed or of the use of better fuel. By the use of superchargers it is expected that the mean effective pressure can be kept at about 140 lb. per sq. in. at the higher engine-speeds, which will mean a tremendous output of power from a small engine.

MARKED advance in constructional details and in engine performance has been made in aircraft-engine development during the 10 years since 1916, at which time the Curtiss OX-5 engine had been brought to its final stage of development. This engine is of eight-cylinder design and has separate cylinders of 4-in. bore and 5-in. stroke disposed in V form in two banks of four cylinders each at 90 deg. to each other. It develops 100 hp. at 1400 r.p.m. and weighs 4.34 lb. per hp. Wherever horsepower or fuel-consumption is mentioned herein, except when otherwise stated, the figures are from tests in which the fuel used was domestic aviation-gasoline.

This engine has a compression-ratio of 4.9 to 1.0 and a brake mean effective pressure of approximately 100 lb. per sq. in. Its performance is fair, as shown in Fig. 1, and, although production of this model has been discontinued, many of these engines are available for use and are being used in considerable number in airplanes employed at airdromes for carrying passengers. They are

[1] M.S.A.E.—Chief motor engineer, Curtiss Aeroplane & Motor Co., Inc., Buffalo.

not suitable for long cross-country work, however, because of their small power output and high ratio of weight to power. The individual cylinders have brazed-on Monel-metal water-jackets and the valves are operated by push-and-pull rods from a camshaft in the engine V, a construction that makes the engine especially well suited for driving motorboats on either fresh or salt water, for which purpose many are used.

The design for a larger engine of the same type with 5-in. bore and 7-in. stroke was started in 1915, but individual steel cylinders were used with a double head that allowed water to circulate around the valve-seats. This engine, as designed, weighed 4.5 lb. per hp. and developed 160 hp. at 1400 r.p.m. It was bulky and did not run smoothly. It was gradually developed, however, until it delivered 250 hp. at 1400 r.p.m., which corresponds to a brake mean effective pressure of about 130 lb. per sq. in. Two bad features were discovered in the development of this model: The design was very poor as regards valve cooling unless the heads were made thick enough to prevent warping, when the construction became too heavy; and, after continued operation, the water passages between the valves became clogged with lime, which deposits much more rapidly on steel cylinders than on aluminum cylinders and resulted in overheating of the valves, particularly with slow circulation of water around them, as in this engine. Sheet-metal water-jackets, either welded or brazed, are always a source of trouble in this respect.

The valve ports were fastened to the heads by long studs and, as there was no water circulation around the valve guides or the ports, the exhaust-valve port was air-cooled by metal fins on the cast-iron elbow. Consequently, any change in temperature of this port or any change in tension of the hold-down studs resulted in a change of shape of the valve-seat. An experimental 12-cylinder 400-hp. 5 x 7-in. engine of this type was built but was not put into production because of its weight of 1100 lb. and its bulk.

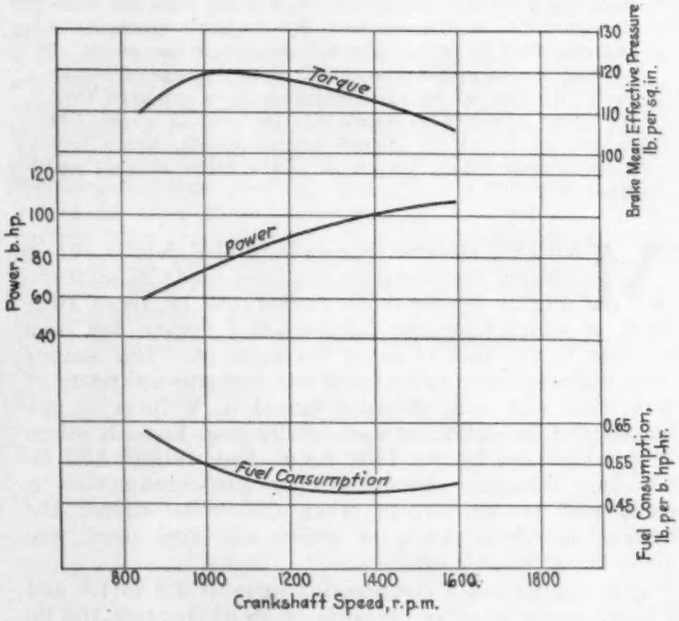

FIG. 1—TEST-PERFORMANCE OF MODEL OX-5 V-TYPE EIGHT-CYLINDER ENGINE

The Curves of Brake Mean Effective Pressure, Brake Horsepower and Fuel Consumption Are from a 50-Hr. Test in Which Commercial Aviation-Gasoline Was Used as Fuel. The Cylinder Bore Is 4 In.; the Piston Stroke, 5 In.; and the Compression-Ratio, 4.9 to 1.0

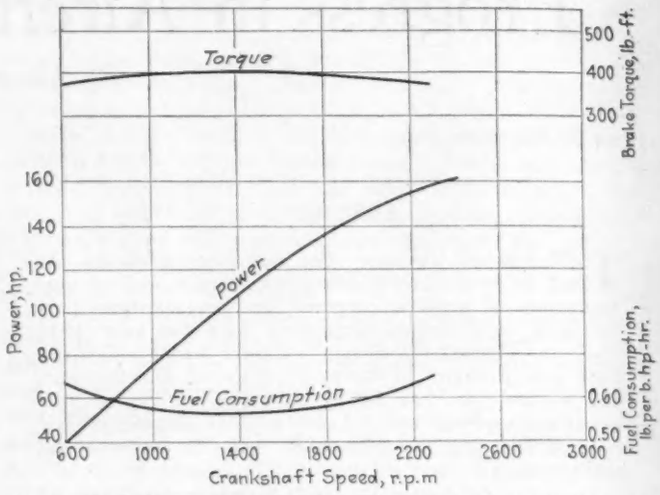

FIG. 2—TEST-PERFORMANCE OF MODEL K-6 SIX-CLINDER ENGINE ON AUTOMOBILE GASOLINE

The Cylinder Bore Is 4½ In.; the Piston Stroke, 6 In.; and the Compression-Ratio, 4.5 to 1.0

BLOCK TYPE SHORTER AND MORE RIGID

The first Curtiss engine that departed from the individual-cylinder design was the Model-AB 12-cylinder 60-deg. V-type engine with 4-in. bore and 5½-in. stroke built in 1916. Operation of the OX-5 and the V-2 models made it evident that very heavy crankcases were necessary to make engines with individual cylinders sufficiently rigid. Moreover, separate cylinders made the engines too long. Therefore the AB engine was built with the aluminum crankcase and water-jacket cast in one piece. Six individual cylinder-sleeves were screwed into each head and the two head-assemblies were bolted to the crankcase. This resulted in a very rigid construction and allowed short center-to-center distances between cylinders. The camshaft drive was at the center of the engine, which made the engine slightly longer than if the drive had been at the end. A single overhead camshaft on each cylinder-head operated four valves per cylinder in conjunction with cross valve-porting. This was accomplished by a T-shaped tappet or cam-follower located between the cams and the valves. The outer ends of the T opened the valves and the leg of the T operated in a guide in the cylinder-head, the cam pushing on the top of the T. This arrangement removed all side thrust from the valve-stems. Fundamentally, this construction is the same as that used on the modern Curtiss engines.

The cylinder-sleeves, as manufactured, were closed at one end, were threaded at the upper end for about 1½ in. and were screwed into the aluminum cylinder-block, which was heated to give a slight shrink-fit on the sleeve. Valve-ports were cut through the cylinder-head after the sleeves were assembled and the valves were seated directly in the head. Thus the heat transmission was through the joint between the steel sleeve and the aluminum head. However, the construction allowed water to come in direct contact with the steel cylinder-walls for the full length of travel of the piston, which is very important for proper piston-cooling. The lower end of the cylinder water-jacket was closed by a composition gasket between a flange on the steel sleeve and the aluminum water-jacket of the engine.

During the test of this engine it was found that the cross-porting arrangement which was necessary with the single-camshaft valve-operating mechanism was not satisfactory, as, to cool the valves properly, too great com-

plication or too much space for the valve-ports would be required for the engine to be kept within reasonable dimensions. Moreover, the engine weight was 725 lb. Hence the AB engine was abandoned, but the general ideas incorporated in the design were good and are embodied in the construction of the latest Curtiss engines.

The 12 and 6-Cylinder V Engines

Models K-12 and K-6, respectively 12 and 6-cylinder engines of 4½-in. bore and 6-in. stroke, were constructed in 1916 and 1917. They had the same integral crankcase and water-jacket construction and the same cylinder-sleeve construction as the Model AB but the cross-porting and single-camshaft arrangement was abandoned and a separate intake-and-exhaust camshaft was provided for each head, without increasing the weight of the valve-operating mechanism. This change simplified the

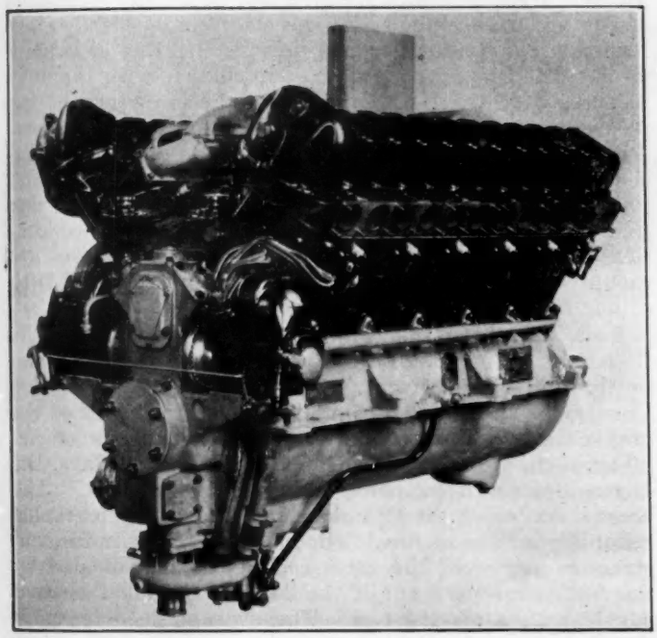

Fig. 3—Curtiss D-12 Water-Cooled Engine Built under Navy Contract in 1921

This Engine Weighs 690 Lb. and Is Rated at 430 Hp. at 2250 R.P.M. It Has Developed 455 Hp. at 2450 R.P.M. in a 50-Hr. Test at McCook Field, Which It Passed without Any Forced Stops or Trouble of Any Kind

design of the cylinder-head casting and made the cooling of the valves much easier. Model K-12 engine developed 400 hp. at 2250 r.p.m. crankshaft speed, with the propeller geared down in a ratio of 3 to 5.

The marked increase in normal crankshaft-speed from 1400 to 2250 r.p.m. is to be noted. Tests of this engine indicated that it was probably a little too optimistic at the time, as the engine never completed a 50-hr. test satisfactorily, principally because of repeated trouble with the reduction gears. These gears functioned well for about 25 hr. of full-throttle operation at 400 hp. and gave good service in flight when little full-throttle running was done.

This model had a four-bearing crankshaft, counterweighted for static balance only. As originally designed, it weighed only 625 lb., but this was increased later to 680 lb. Had the reduction gears been dispensed with in the original design, the engine would have been far ahead of its time in both design and performance. The normal engine-speed could have been lowered with some

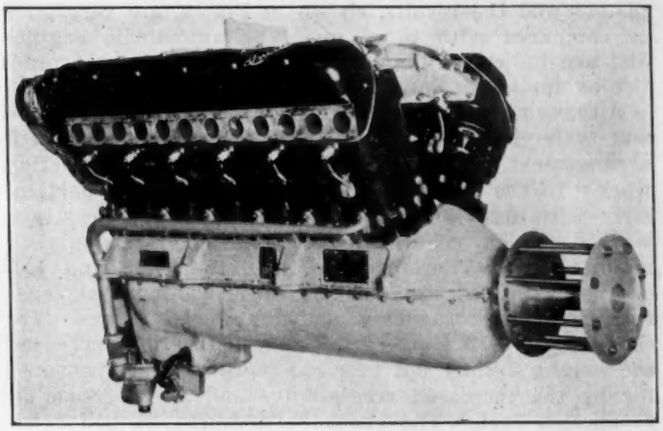

Fig. 4—Model V-1400 12-Cylinder Engine Built in 1924

A Weight-Ratio of 1.10 to 1.33 Lb. per Hp. Has Been Attained in This Engine, Which Passed a 50-Hr. Test in 7 Working Days. It Develops from 505 to 520 Hp. at 2100 R.P.M., with Low Compression. Note the Simplicity and Sturdy Construction of the Crankcase. The Average Fuel-Consumption during the Test Was 0.49 Lb. per B.Hp-Hr.; the Oil Consumption, 0.018 Lb. per B.Hp-Hr.; and the Oil Temperature Difference, 12 to 14 Deg. Fahr.

resultant decrease in power and still the engine would have been very satisfactory.

The K-6 model weighs 420 lb. and delivers 150 hp. at 1700 r.p.m. Several hundred of these engines are now in service and are far more reliable than the Model OX-5, which has a good reputation in this respect. This six-cylinder engine weighs slightly less than the eight-cylinder OX-5 and delivers 50 more hp. It is not geared. Its performance provides the basis for the foregoing statement that Model K-12 would have been a much more advanced development had the reduction gears been omitted, about which more will be said later. For the purpose of testing with automobile gasoline, Model K-6 engine No. 60 was fitted with very low-compression

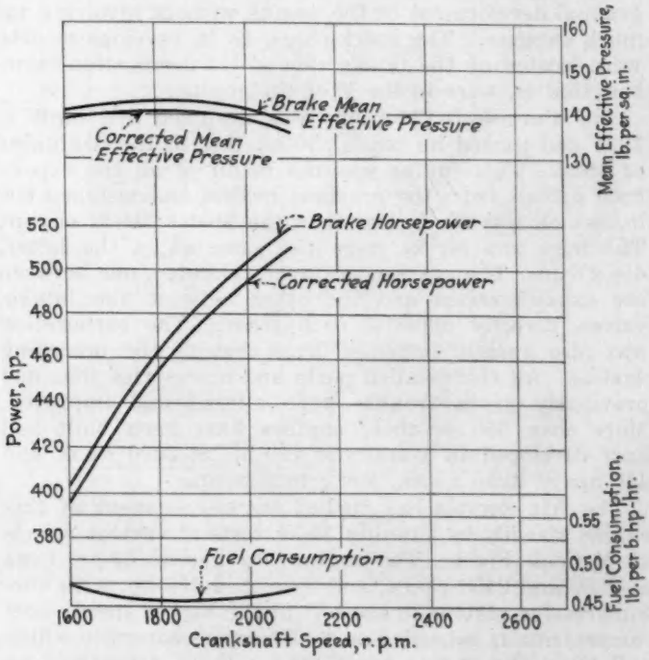

Fig. 5—Test-Performance of the V-1400 Engine

The Curves of Brake and Corrected Mean Effective Pressure and Horsepower and of Fuel-Consumption Are from a Test-Run Using a Blend of 20-Per Cent Benzol and 80-Per Cent Aviation Gasoline. The Engine Has a Bore of 4⅞ In., a Stroke of 6¼ In., and a Compression-Ratio of 5.5 to 1.0

pistons and the results, shown in Fig. 2, are very good as compared with those given by automobile engines and are indicative of the possibilities of aircraft practice as applied to automobile engines.

Although the integral construction of the crankcase and water-jacket made an exceedingly light and stiff arrangement, the design was not good for production work. In the 12-cylinder V-type of crankcase, particularly with 6 cylinders in a block, the large castings warped, which necessitated considerable scrapping in manufacture. Therefore, in 1919, the K-12 and K-6 engines were redesigned to have the water-jacket separate from the crankcase and the model names were changed to C-12 and C-6. This construction increased the weight slightly but this was more than compensated for by the increased accessibility and the decrease in production cost. The crankshafts were changed from the four-bearing to the seven-bearing type, which decreased the cost of the crankshaft and eliminated counterweights. In other respects the C-6 and C-12 engines were no more advanced than the K models. The C-12 was discontinued but the C-6 engine is built for commercial aviation service and is regarded as one of the best water-cooled engines in the 160-hp. class today. It weighs the same as the K-6 engine, namely, 420 lb.

V-Type Engines Without Reduction Gears

In 1920 the CD-12 engine was produced from the same 4½ x 6-in. 12-cylinder engine but without reduction gears. It was really a C-12 engine redesigned to determine definitely whether or not the major parts would be satisfactory for future development. This engine, shown in Fig. 3 and built under Navy contract, went through a 50-hr. test at 375 hp. at 2000 r.p.m. at McCook Field and later developed 385 hp. at that speed. Some trouble developed with the accessory drives and small details but the major parts came through without trouble. The normal speed had been dropped to 2000 r.p.m., as it was thought best to keep the speed low to provide for gradual development of the engine without involving too much expense. The spark-plugs, as in previous models, were located on the intake side of the combustion-chamber, that is, were in the V of the engine.

The Curtiss D-12 engine was designed and built in 1921 and passed its official 50-hr. test in the beginning of 1922. This engine was the result of all the experience gained from the previous models and weighed 690 lb., which was 30 lb. less than the Model CD-12 engine. The bore and stroke were the same as in the latter, 4½ x 6 in. The spark-plugs were relocated, one between the exhaust-valves and the other between the intake-valves, directly opposite each other. The carburetion was also greatly improved over that of the preceding models. All the detailed parts and accessories that had previously given trouble were altered and improved. More than 350 of these engines have been built and have developed an average of 410 hp. at 2000 r.p.m. and 440 hp. at 2250 r.p.m., low compression.

The Air Service has pushed the development of this engine steadily by running 50-hr. tests at various speeds at McCook Field. The engine has passed 50-hr. tests at 2250 and 2450 r.p.m., and developed 455 hp. with low-compression pistons in the test at the higher speed. Low compression is regarded as that compression-ratio which will allow the engine to operate without detonation on domestic aviation-gasoline containing no "dope." This high-speed 50-hr. test was run without any forced stops or trouble of any kind. The engine is now rated at 435 hp. at 2300 r.p.m. Operation for more than 200 hr. between overhauls is being obtained in service with this engine.

V-1400 Model Lighter and More Powereul

During the latter part of 1924 the Curtiss V-1400 engine, shown in Fig. 4, was designed and built. This model, which has a bore of 4⅞ in. and a stroke of 6¼ in., develops from 505 to 520 hp. at 2100 r.p.m., low compression, and more than 600 hp. at the higher speed and with high-compression pistons. (See Fig. 5.) It is lighter than the production D-12 engine, as it weighs only 685 lb., dry, and fits in the same engine-bearers. It is slightly narrower than the D-12 owing to the double camshafts being driven through three spur-gears instead of two, the bevel drive being attached to the third spur-gear, which is mounted below the two spur-gears on the ends of the camshafts. The sleeve construction is the same as in the D-12 except that the heads of the sleeves are open and are screwed into the aluminum heads against shoulders on the sleeves. The valves are seated on aluminum-bronze inserts in the aluminum head. The cooling water comes in contact with the steel sleeves, as in the D-12 engine, and the lower end of the sleeve is sealed with a composition gasket, as before. Provision is made to use either battery or double-magneto ignition. The magneto is a Splitdorf double machine that operates with both armatures on one shaft and with two contact breakers, two coils and two condensers, all in the same machine. The distributors are mounted on the ends of the camshafts and are used with either the battery or the magneto ignition.

This V-1400 engine, which weighs from 1.10 to 1.33 lb. per hp., depending on the power output, is more than 50 lb. lighter than its nearest competitor, either in this Country or abroad. The simplicity and sturdiness of the crankcase will be noted in Fig. 4. During its official 50-hr. test, which was completed in 7 working days, the engine improved in power throughout the test. The short duration of the test alone indicates the remarkable reliability of the engine. The new type of cylinder construction improved the valve cooling, as is indicated by the fact that only 3 out of the 24 exhaust-valves showed any leakage after the test. The average fuel-consumption during the test was 0.49 lb. per b.hp-hr. The average oil-consumption was 0.018 lb. per b.hp-hr., and the oil-temperature difference between inlet and outlet was only from 12 to 14 deg. fahr.

The small difference in oil temperature is most interesting, since a low oil-temperature difference is highly desirable. With the production of very high horsepower in small units it is necessary to use an oil-temperature regulating device in an airplane owing to the small crankcase area that is available for radiation. If the temperature difference is large, considerable heat must be dissipated, which presents a difficult problem. Air-cooling of oil has not been found satisfactory, since the oil in the cooler congeals rapidly on the surfaces of the cooler and effectively insulates the remaining body of oil. In 1919 the Curtiss Company successfully adapted to its racing airplanes a method of oil-cooling by the use of the cooling-system water. A small-core radiator was inserted in the intake side of the water system. The oil was allowed to circulate through this core in the space usually provided for water in the conventional radiator, and the water was circulated inside of the cartridge tubes in the space ordinarily used for air-flow. It was found that by this arrangement the oil temperature could be kept very close to the temperature of the water flowing into the engine, which is a very satisfac-

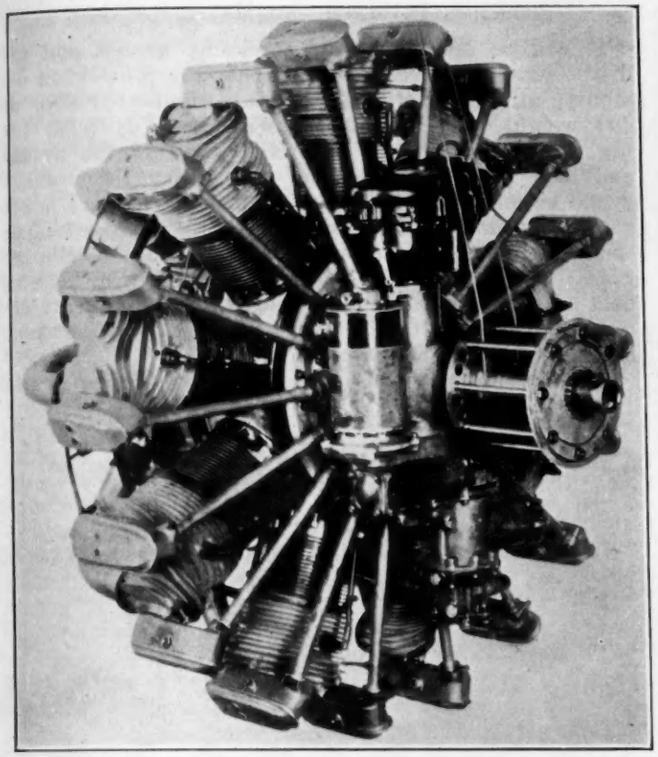

FIG. 6—CURTISS NINE-CYLINDER AIR-COOLED RADIAL ENGINE BUILT IN 1925

It Develops 400 Hp. at 1650 R.P.M., Which Corresponds to About 130 Lb. per Sq. In. Brake Mean Effective Pressure, and Weighs 800 Lb., Dry. The Installed Weight Is About the Same as That of the V-1400 500-Hp. Water-Cooled Engine but Can Be Reduced to Less Than 700 Lb. as the Result of Experience Gained in the Last 2 Years. It Cannot Be Run at High Speed on Account of the Heavy Reciprocating Parts

tory temperature for the oil. The warm water heated the oil during cold weather and cooled it during hot weather. If the temperature-difference and the quantity of heat that is dissipated to the oil is small, light oil-coolers can be used. In an engine having a large quantity of heat to dissipate through the oil, to put sufficient cooling surface in the oil radiators to obtain the desired results is often impossible on account of the small space that is available in an airplane. The advantage of low heat-rejection to the engine oil is therefore evident.

THE NINE-CYLINDER RADIAL AIR-COOLED ENGINE

Another distinct and different development that we have undertaken during the last year has been the production of a 400-hp. nine-cylinder air-cooled radial engine, with the realization that a definite field for the air-cooled engine exists. Just what type of air-cooled engine will be used eventually is uncertain. Without doubt various types will be used to meet the particular requirements of different services. Elimination of the water and the radiator is desirable and should decrease maintenance cost and increase reliability.

At present we are building a conventional type of radial engine, as shown in Fig. 6, first, because of the demand for that type, and, second, because more is known about this type of engine, regarding cooling in particular. This engine is now in the development process and indicates that it will become a very useful type. It develops 400 hp. at 1650 r.p.m., which corresponds to approximately 130 lb. per sq. in. brake mean-effective-pressure, and weighs 800 lb., dry. Its dry weight, which figures 2 lb. per b.hp., is much greater than the dry weight of the 500-hp. Curtiss V-1400 engine, namely, 685 lb. However, the installed weight of both engines will be about the same and, from knowledge gained in the last 2 years, the radial air-cooled engine of 400 hp. can be reduced to less than 700 lb.

One serious disadvantage of the radial engine is that it cannot be run at high speeds on account of the heavy reciprocating parts. Air-cooled V-type engines are being studied and an air-cooled Liberty-12 engine of 4⅝-in. bore has been built and tested by the Air Service successfully. The cylinder of the 400-hp. air-cooled engine was developed by the Engineering Division at McCook Field, and I know of no water-cooled engine that has any better valve cooling than this cylinder. Exhaust-valves have been run at full throttle, passing more than 40 hp. for more than 100 hr. without showing any appreciable change in condition. As the power of the engine is increased above 500 hp., the weight per horsepower of the water-cooled and air-cooled engines, when installed, will be about the same, and at powers of more than 1000 hp. the water-cooled engine will begin to have the advantage over the air-cooled engine in the installed weight. The reason for this is that the block construction of the water-cooled engine allows short center-distances between cylinders, and in larger powers than 500 hp. the indications point to the V and X types of air-cooled engine as preferable to the radial type. V-type air-cooled engines will require large center-distances between the cylinders, which means a long crankshaft, long crankcase and other long parts that are necessary in any engine and will run into weight.

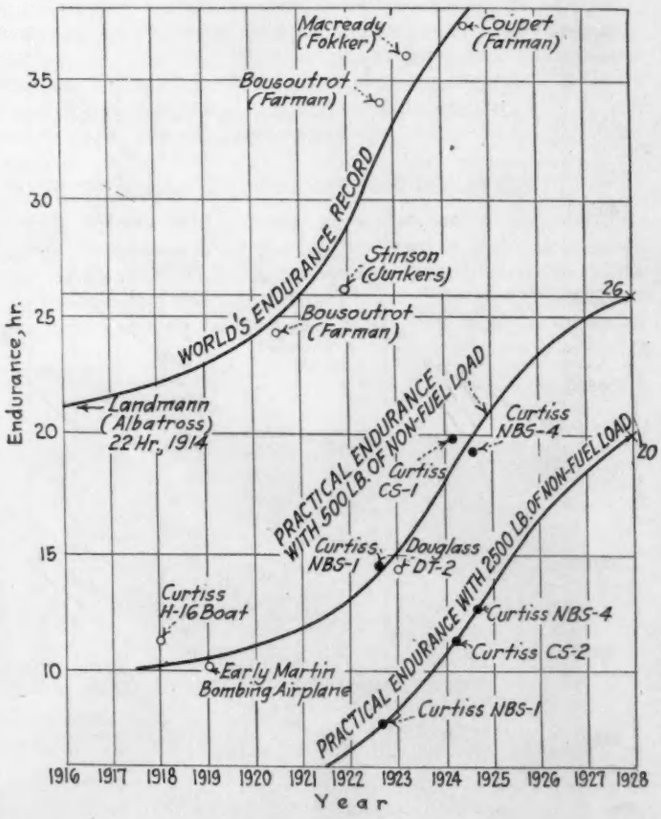

FIG. 7—ACTUAL AND EXPECTED INCREASE IN AIRPLANE ENDURANCE IN 12 YEARS

A New World's Record of 45 Hr. 11 Min. 59 Sec. Was Made in France in August, 1925, with an Airplane Carrying No Pay Load, but This Is Not Shown on the Top Curve. That by 1928 an Endurance of 26 Hr. with 500 Lb. of Pay Load and of 20 Hr. with 2500 Lb. of Pay Load Will be Possible, as Indicated by the Projection of Middle and Bottom Curves, Seems Likely

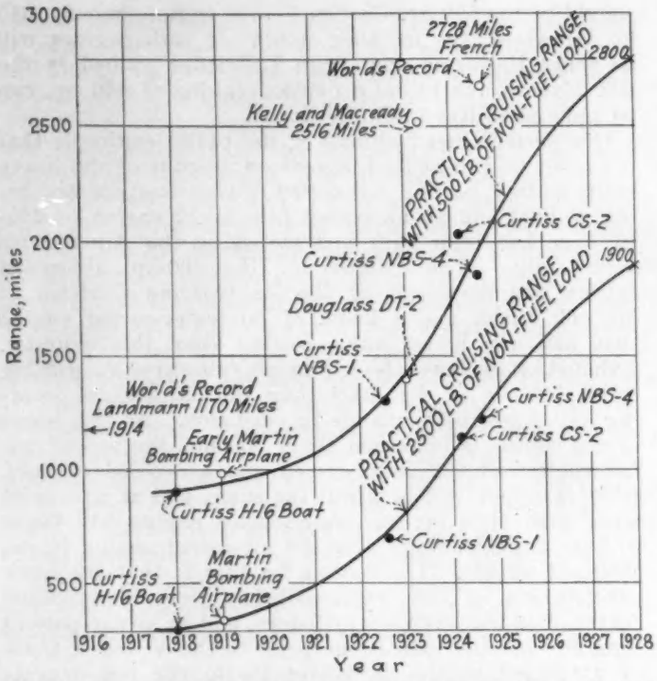

FIG. 8—ACTUAL AND PREDICTED INCREASE IN AIRPLANE FLYING-RANGE

A Non-Stop World's Record of 2,728 Miles Was Made in France in August, 1925, as Indicated above the Upper Curve. Prediction Is Made That in 1928 a Practical Cruising-Range of 2800 Miles with 500 Lb. of Pay Load and 1900 Miles with 2500 Lb. of Pay Load Will Be Reached

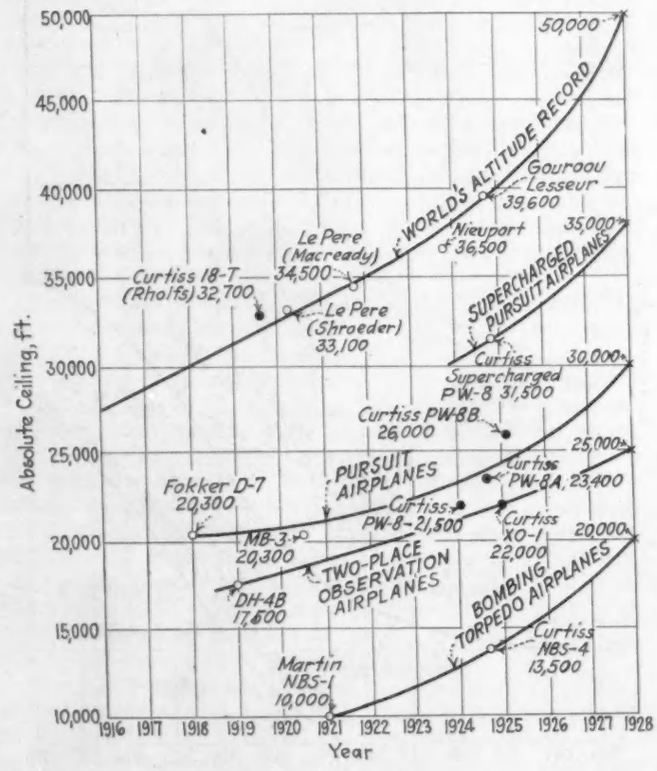

FIG. 9—INCREASE IN AIRPLANE CEILING, ACTUAL AND PREDICTED, DURING 10 YEARS

The World's Altitude Record of 32,700 Ft. without a Supercharged Engine Was Made in a Curtiss Triplane in 1919 and Is Likely To Stand for Many Years. The Later Records Were Made with Supercharged Engines and the Prediction Is That 50,000 Ft. Will Be Reached in 1928. Pursuit Airplanes Have Had 10,000 Ft. Added to Their Ceiling Ability by Use of the Supercharger, as Shown by the Second and Third Curves from the Top, and Another 7000 or 8000 Ft. Probably Will Be Added in the Next 3 Years

PROBLEMS INVOLVED AND MATERIALS USED

It will be seen from the foregoing models and the discussion of their construction that the problem in designing aircraft engines is to obtain the best relation of (*a*) weight, (*b*) frontal area, (*c*) cost, (*d*) bulk, (*e*) high performance, and (*f*) reliability. If the weight and bulk requirements were unnecessary the problem would be much simpler. The aeronautic engineer is not held down on cost to anywhere near the same extent as the automobile engineer when designing automobile engines; however, that he also has competitors in his own field must be borne in mind and, while the aircraft engine is strictly limited in weight, it must operate at very high duty and with extreme reliability.

All of these problems are involved with the proper

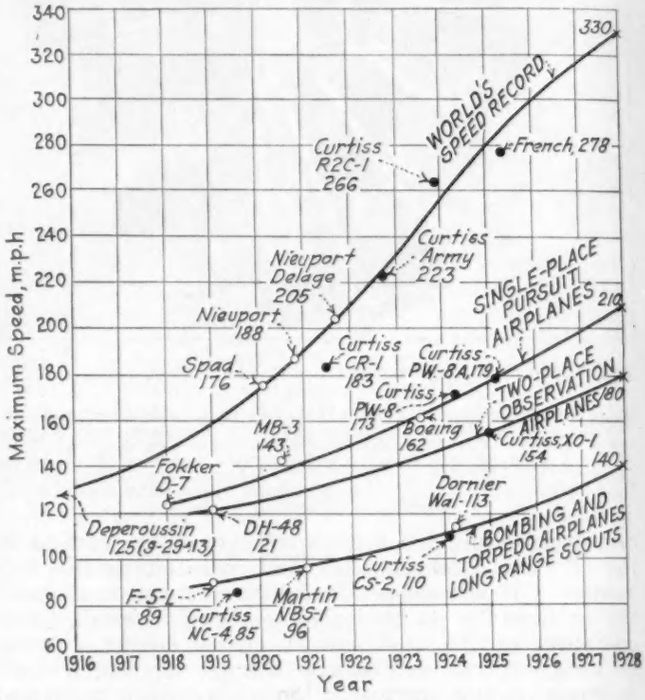

FIG. 10—INCREASE IN AIRPLANE SPEED, ACTUAL AND PREDICTED DURING 12 YEARS

The World's Record of 266 M.P.H. for Racing Machines, Made in a Curtiss Airplane at Detroit in 1923, Was Raised to 278 M.P.H. by the French in 1924. The French Attain Their Records, However, by Operating at Very High Landing-Speeds. The Schneider Cup for Seaplanes Was Brought To This Country from England in 1923 by the Victory of the Curtiss CR Racing Machine, and in 1925 Was Won Against England and Italy at Baltimore with a World's-Record Speed of 233.8 M.P.H. Racing Has Led To the Development of Service Pursuit-Airplanes That Will Fly at 175 M.P.H.

arrangement of parts, which can be secured only as a result of experience, and with the proper selection of materials. More than 40 different kinds of material are used in the modern aircraft-engine. The most interesting materials are the light and unusual alloys. Magnesium probably is one of the more interesting of these to engineers who are not connected with the aircraft industry. This alloy is 40 per cent lighter than aluminum, has an average tensile-strength of 20,000 lb. per sq. in. and an elongation of 4 per cent. It is comparable in strength and elongation with the best non-heat-treated commercial aluminum crankcase-alloys. The lighter alloys of magnesium, alloyed with about 5 per cent of aluminum, are much less subject to corrosion than the original alloys that were produced. This alloy has been cast in almost every form that is used in an aircraft engine; however, the present cost of production prohibits its use in quantity. It is hoped that in the

future sufficient quantities will be available so that the material can be used with success in our later models and in production engines. With this material available economically and with higher engine-speed, remarkable performances may be expected.

Aluminum-bronze is another material that has come into extensive use in aircraft engines. This makes a very remarkable valve-insert metal, as its coefficient of expansion is about the same as that of aluminum. The valve-seat, after a few hours of engine running, presents a mottled appearance almost as if the metal were pitting. We find, however, that this is not the case and to recut the seats because of this appearance is not wise. The valves will continue to function for hundreds of hours without trouble with this construction if the proper cooling is provided around the valve-insert. The material can be heat-treated to give about 200 Brinell hardness for this work. In alloys with iron and steel, the Brinell hardness can be raised to more than 300 by heat-treating.

Duralumin is an alloy with which nearly everybody in the automotive industry today is familiar. It is used extensively in modern engines, in both the cast and forged forms. It is particularly advantageous in the forged form owing to the small amount of work that is necessary on the forgings after they are received. The finish of the forgings is perfectly satisfactory and it is necessary only to remove the flash before putting the forgings into the machine-shop. We have found that the cast high-tensile aluminum-alloy is unusually satisfactory for cylinder-heads. The average tensile-strength is more than 30,000 lb. per sq. in. and elongation about 6 per cent. It is extremely non-porous and very uniform in texture, and it machines very satisfactorily. The cylinder-heads and water-jackets of our water-cooled engines and in the crankcases of the air-cooled engines are the places where this alloy is used. It is approximately 10 per cent lighter and nearly 100 per cent stronger than the usual crankcase aluminum-alloys.

Y-alloy is an alloy of aluminum with copper, nickel and magnesium. It is used for pistons in all of our engines and in the cylinder-heads of our air-cooled engines. This material is a light aluminum-alloy owing to its low copper-content, and is a wonderful bearing material. It seems to be as strong as the high-tensile aluminum-alloys similar to duralumin, in the heat-treated condition, but has a marked advantage over them in the property of great strength at high temperature. Y-alloy apparently has not been used to a great extent in the automotive field except in pistons, because of its high cost due to the heat-treating operation. High-silicon aluminum-alloys are used for sections varying from 3/32 to ⅛ in. in thickness.

FIG. 12—CURTISS CR RACING MACHINE THAT WON THE SCHNEIDER CUP FOR SEAPLANES IN 1925

Lieut. J. H. Doolittle, on the Pontoon, Piloted the Machine in the Baltimore Race against English and Italian Entries and Set a World's Record of 233.8 M.P.H. This Machine Has Established a World's Record for Seaplanes of 245.1 M.P.H. Over a 3-Km. (1.86-Mile) Course

As an indication of the large number of materials that are required to obtain maximum strength with minimum weight in the smallest possible space, one cylinder-block of our 500-hp. engine contains 14 different materials, as follows: duralumin, magnesium, aluminum-bronze, nickel-chromium steel of two analyses, carbon-steel of two analyses, cast iron, brass, copper, cold-rolled steel, drill rod, chrome-vanadium steel, and silchrome steel.

PROBABLE FUTURE ENGINE-DEVELOPMENT

The future development of water-cooled aircraft engines probably will be the combination of reduction gearing from the crankshaft to the propeller with high engine-speeds and supercharging. The reduction-gear problem has been solved and gears can now be made as

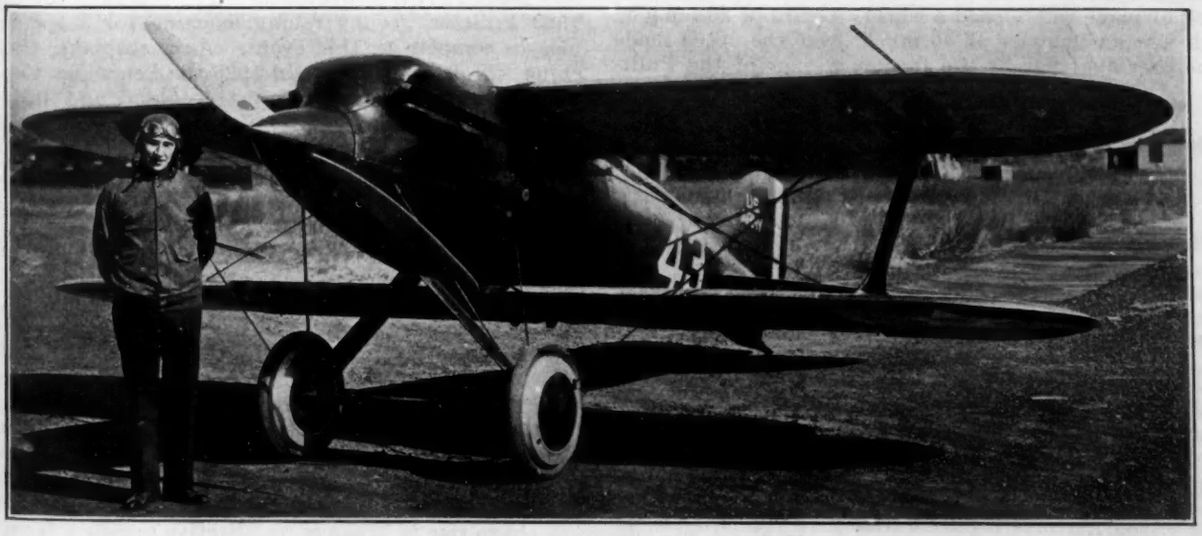

FIG. 11—CURTISS ARMY 1925 RACING AIRPLANE THAT SET THE 100-KM. (62.14-MILE) RECORD AT 248.8 M.P.H.

Lieut. Cyrus Bettis, Seen at the Left, Piloted the Machine to Victory in the Pulitzer Trophy Race at Mitchell Field, N. Y., in Which This World's Record Was Made. The Machine Was Driven by a V-1400 600-Hp. Engine

reliable as the engine. The air-cooled engine (Fig. 6) is already equipped with a supercharger, which is built into the engine and included in the given weight. With availability of lighter alloys and with supercharging and reduction gears, a weight close to 1 lb. per hp. is well within a possibility. The rotary inductor on the Curtiss 400-hp. radial engine has made possible a fuel economy of less than 0.5 lb. of gasoline per hp-hr. at one-quarter throttle, which is unusual.

How Airplane Performance Has Improved

The airplane has been improving in performance together with the engines, as shown in the curves of endurance, ceiling, speed and range. An endurance record of 45 hr. 11 min. 59 sec. was made in France in August, 1925, in the type of airplane that carries no pay load. That an endurance of 26 hr. will be possible in 1928 with a pay load of 500 lb. and 20-hr. endurance with a pay load of 2500 lb. seems likely. It will be noted by the bottom curve in Fig. 7 that at present nearly 13-hr. endurance is possible with a pay load of 2500 lb. The airplane flying-range has also increased considerably since 1918, and the prediction now is that the 2800-mile range will be reached in 1928 and that 1900 miles will be the range with a useful load of 2500 lb. The 2728-mile mark was reached in France in August, 1925, as shown above the upper curve in Fig. 8.

The real advance in increase of ceiling since 1920 has been the result of using the supercharger. The Curtiss 18-T triplane attained an altitude of 32,700 ft. in 1919 without a supercharged engine (See Fig. 9), and this record probably will stand for many years. The predictions are that 50,000 ft. will be reached in 1928 with the use of a supercharger, although this may be optimistic. The advantages of the supercharged engine for this work are evident. Pursuit airplanes have had 10,000 ft. added to their ceiling by the use of the supercharger, and another 7000 or 8000 ft. probably will be added during the next 3 years. Large bombing airplanes will, no doubt, be operating successfully at 20,000 ft. by 1928. Of course, greater power at altitude means greater speed.

The speed of airplanes, which is associated directly with the improved design of engines, owing to the necessity for small frontal area and light weight, has increased rapidly during the last 5 years, as shown by the curves in Fig. 10. In Detroit, in 1922, the Curtiss Army racing airplane established a world's record of 223 m.p.h., which was an increase of 40 m.p.h. over the speed made in the previous year by the former winner of the Pulitzer Trophy Race. This speed was increased to 266 m.p.h. in 1923, and in November, 1925, the speed was raised to 278 m.p.h. by the French.

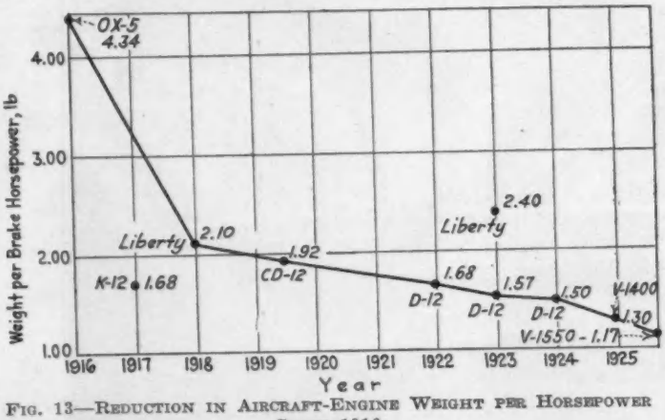

Fig. 13—Reduction in Aircraft-Engine Weight per Horsepower Since 1916

Engine Weight Has Been Decreased from More Than 4.33 Lb. per Hp. to Less Than 1.30 Lb. per Hp. during the 10 Years. Note the Low Normal Speed of the V-Engine in 1925 and the Position on the Curves of the Liberty-12 Engine. The Data Are for Performance with Low Compression and Undoped Fuel

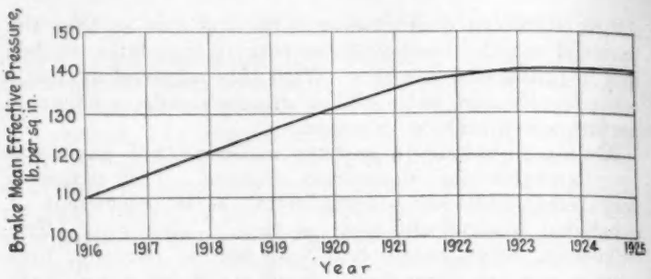

Fig. 14—Rise in Brake Mean-Effective-Pressure of Aircraft Engines During 9 Years

This Increase Has Been Made with a Compression-Ratio That Is Suitable for Domestic Aviation-Gasoline Containing No Anti-Knock Preparation and Is Due Principally to Improvement in Spark-Plugs. No Radical Improvement in Power of the Normal Engine Can Be Expected Except as the Result of Raising the Normal Number of Revolutions per Minute or Use of Better Fuel

To learn officially that many features of the Curtiss D-12 engine were incorporated in the French Hispaño engine that was used in this record-breaking machine is interesting. That the French attain their records by operating at very high landing-speeds is well known. By so doing they are not progressing in either airplane or engine design as rapidly as we are in this Country. As an example, we could reduce the wing area of our present racing machines to raise the landing speed from the present minimum of 75 m.p.h. to 100 m.p.h. and raise the top speed from 266 to more than 290 m.p.h. Without question we could get this speed record now by sacrificing our low landing-speed, but speed range, that is, the difference between minimum and maximum flying-speeds, is much more desirable than merely high speed.

The 100-km. (62.14-mile) record for speed airplanes was broken by the Curtiss Army 1925 racing airplane fitted with a Curtiss V-1400 engine. (See Fig. 11.) This record stands now at 248.8 m.p.h. No attempt was made in 1925 in this Country to break the 3-km. (1.86-mile) record.

In 1923 the Schneider Cup for seaplanes was brought to this Country from England by the victory of the Curtiss D-12 engine and the Curtiss Model CR racing machine shown in Fig. 12. No competition for this cup was held in 1924, although the Navy prepared the Curtiss 1923 Pulitzer Trophy racing machine for seaplane service to compete in this event. As a seaplane, this machine will do 227 m.p.h. In 1925 the Schneider Cup race was won at Baltimore against England and Italy, the latter country using a Curtiss engine, at a speed of 233.8 m.p.h., which is a world's record. The same Curtiss racing airplane made 245.1 m.p.h. over a 3-km. (1.86-mile) course, the fastest speed ever made by a seaplane, and established another world's record.

Racing has led to the development of service pursuit-airplanes that will fly at 175 m.p.h., which is greatly in excess of the performance of about 140 m.p.h. in 1920 and 125 m.p.h. made in 1918 by service airplanes.

The curves in Fig. 13 show the increase in performance of airplane engines since 1916. The decrease in weight has been steady from more than 4.0 lb. per hp. to less than 1.3 lb. per hp. The position on these curves of the Liberty-12 engine, with which most engineers are familiar, will be noted. The radical change in the normal number of revolutions per minute is indicated clearly.

A sharp rise in brake mean effective pressure from 1916 to 1919, as shown in Fig. 14, is due principally to improvement in spark-plugs. To keep the compression-

ratio at a low figure during this development period until the spark-plug manufacturers could produce a satisfactory plug for the high-duty aviation engine was necessary. At present the compression-ratio is limited by the characteristics of the fuel that is available. The highest ratio that we consider advisable when using domestic aviation-gasoline is 5.5 to 1.0. With a compression-ratio of 6.00 or 6.25 to 1.00 about 30 per cent of benzol must be used with the gasoline to prevent detonation.

The curves of brake mean effective pressure indicate that no radical change in power of the normal engine can be expected except as the result of raising the normal number of revolutions per minute or the use of better fuel. It is expected that, by the use of superchargers, the mean effective pressure can be kept at about 140 lb. per sq. in. at the higher engine-speeds, which will mean a tremendous output of power from a small engine.

ANTI-FREEZE SOLUTIONS AND COMPOUNDS

AS published in the July issue of THE JOURNAL, the Semi-Annual Meeting paper by H. K. Cummings entitled Anti-Freeze Solutions and Compounds contained a number of errors. These occurred principally in the abstract printed on p. 93 and also on p. 95 in connection with Fig. 1 and on p. 99 in referring to the loss of weight of the brass strips used in connection with the corrosion tests.

The changes that should be made in the abstract are given below. In cases where the change is more than a straight substitution or omission of a word or a phrase, the words that should be omitted are enclosed in [ ] and the words to be added are printed in italics.

Paragraph 1, last sentence. The word "glycols" should be substituted for "a patented by-product of glycerine."

Paragraph 3, last sentence. Curves [of the] *based on viscosity* determinations [of] *for* such [viscosity] *liquids over a wide temperature range* are shown.

Paragraph 4, the last word in the sixth line should be "calcium" instead of "magnesium."

Paragraph 5. In the last sentence of this paragraph the word "glycerine" should be omitted.

Paragraph 6, the last sentence. Glycerine [is] *solutions of higher specific gravity than 1.144 are* not recommended for use in cars having thermosiphon circulation, because of [its] *their* high viscosity at low temperatures.

Paragraph 7, first sentence. Ethylene glycol is [a patented by-product of glycerine that] *made indirectly from petroleum or ethyl alcohol and* sold in the winter of 1925 and 1926 at about the same price as glycerine.

Although a reference was made on p. 94 to the freezing points of 55 and 60-per cent invert-sugar solutions as being shown in Fig. 1, these points were not shown on the cut as originally printed. The cut corrected to show this information is printed herewith.

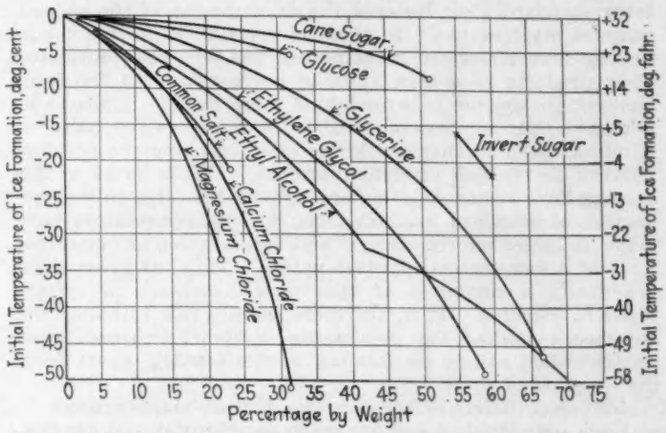
Initial Temperature of Ice Formation, deg. cent
Initial Temperature of Ice Formation, deg. fahr.
Percentage by Weight
Cane Sugar
Glucose
Glycerine
Ethylene Glycol
Ethyl Alcohol
Invert Sugar
Common Salt
Calcium Chloride
Magnesium Chloride
0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50
+32 +23 +14 +5 -4 -13 -22 -31 -40 -49 -58
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

FIG. 1—VARIATION OF FREEZING-POINT OF SOLUTIONS OF PURE SUBSTANCES WITH VARIATION OF PERCENTAGE BY WEIGHT

The Circles Indicate the Concentrations, or Densities, That Give Maximum Protection against Freezing. Although 14-Per Cent Solutions of Common Salt and of Calcium Chloride with Water Have the Same Freezing-Point, the Minimum Freezing-Point Obtainable with the Former Is — 21.3 Deg. Cent. (—6.3 Deg. Fahr.), Whereas That Obtainable with Calcium Chloride Is —51.0 Deg. Cent. (—59.8 Deg. Fahr.). Glucose-Water and Cane Sugar-Water Solutions Have Minimum Freezing-Points above —10 Deg. Cent. (14 Deg. Fahr.), Whereas All the Others Will Give Protection at Temperatures Down to at Least —20 Deg. Cent. (—4 Deg. Fahr.)

The solution used by the Bureau of Standards in estimating the corrosiveness of radiator liquids was a 20-per cent sodium-chloride solution containing 1 per cent of sodium carbonate. In connection with the average loss of weight of the brass strips mention should have been made that this loss occurred after a 15-day test by being immersed in the 20-per cent sodium-chloride solution.

TECHNIQUES OF ENGINEERING EDUCATION

WHAT is the proper function and scope of the college of engineering? Is it a variant to the arts college, affording a somewhat different type of general education, or is it a professional school in the strict sense, like schools of divinity, law and medicine? Plainly it is an intermediate type.

A college of engineering derives its essential quality from engineering as a type of activity, rather than the engineer as a type of person. It is related to the broad economic field of public works and industry and not to the engineering profession alone. The bonds of the college to the profession are important and may well be more intimate, but the one is not merely the subsidiary of the other and properly subject to its dictation and control. If the aims of the engineering college are less restricted and definite than those of the purely professional school, they are far more definite and concrete than those of the liberal college.

For the sanction of a definition, we may turn to the walls of the library of the United Engineering Societies, where we find inscribed in letters of gold the words

> Engineering—the art of organizing and directing men and of controlling the forces and materials of nature for the benefit of the human race.

a happy blend of the fundamentalism of Tredgold with the modernism of Stott. Usage gives to sweeping definitions of this type a more restricted sense. Engineering tradition makes the control of the forces and materials of nature the central and primary factor and subordinates to this purpose the organization and direction of men. Our definition implies that engineering has three distinctive qualities. The first is a scientific technique for the control of the forces, materials and energy of nature; the second is a technique for the organization of human effort; and the third is a technique for appraising the resulting benefits to mankind. A reasonably complete education in engineering must include these three elements. Whatever else it includes is on common terms with liberal education, to enrich personal life and fit men for a worthy place in human society.—W. E. Wickenden in a report to the Society for the Promotion of Engineering Education.

AMERICAN MACHINE-TOOLS IN GREAT BRITAIN

A LARGE proportion of American machine-tools may be found in almost every automobile factory in Great Britain. So far as production milling, crankshaft-grinding, automatic screw and cylinder-boring and grinding machines are concerned, and even in the types of machine-tools where British manufacturers excel, namely, turret lathes and drilling and boring-machines, a large proportion of equipment of foreign manufacture is to be found.

The prevailing state of affairs generally can be traced very largely to the much larger home-market that American machine-tool builders enjoy. This and the low prevailing labor standard have fostered the development of the special-purpose machine-tool. In these circumstances it is not surprising that American machine-tool builders have developed their products to a high state of perfection. At the same time, if the matter is investigated more deeply, it has to be admitted that an insular outlook or conservative habit of mind has been a considerable factor in checking the development of the British machine-tool trade. While firms in this country have been competing one against the other in the production of standard machine-tools, foreign competitors have made progress in the design and construction of machine-tools of a semi-special-purpose nature. This has given them practically a command of the world's markets in certain types of machine. It is, therefore, hardly fair to blame the automobile builder for purchasing equipment abroad when its equivalent cannot be obtained in this country, apart from the question of price.

Nothing will induce the average British manufacturer to sink his individuality and set aside pet theories and fancies, although these may have no substantial foundation. While it may be impossible at present greatly to extend our own markets, nothing can prevent British companies from extending their own outlook. A broader vision would take into account the advantages of specialization among manufacturers. A narrowing-down of the field of activity coupled with concentration of effort would probably be as effective on a smaller scale as an extension of markets.

Another difficulty invariably arises in this country, namely, that when radical changes are contemplated not sufficient ruthlessness is exercised in scrapping old equipment or in the revision of methods. The tendency is to feel the way timorously, so that by the time the desired changes have been effected what were once new and uptodate methods have become obsolete, and further changes are necessary. While caution is, of course, necessary, it should be possible to forecast the effect of such alterations over a period of at least 2 years. To decide fearlessly whether the changes shall be made is then an absolutely necessary step if progress is to be made.

Another aspect of the same problem is found in the fact that in this country the technical man is at a disadvantage as compared with his colleagues on the commercial side of the industry. To reiterate the fact that British engineers are second to none is of little use if the ability that they undoubtedly possess must still continue to struggle for expression in the face of all manner of discouragement and difficulty. Here again a more farsighted view would regard the man who has the ability to organize manufacture on cheap and efficient lines as of primary importance. At present first place is usually given to those who perform the secondary function of handling and distributing goods without adding to their value. Given sufficient attention to the manufacturing side, the increase in efficiency must bring prices down to a level where costly selling organizations are no longer necessary.—*Automobile Engineer.*

COKE PRODUCTION AND BENZOL

COKE is produced in the United States by a group of four industries, which are related in the sense that the product is to some extent interchangeable but are sharply differential as to location, method, equipment, and organization. Besides that produced in the familiar beehive and by-product ovens, coke is obtained in the refining of petroleum, the manufacture of coal gas and the refining of coal tar.

Petroleum coke can be dismissed with a few words. In refining crude oil the ultimate residue is often in the form of a porous, carbonaceous mass. Its properties are much like those of coke made from coal, except that it is finer in texture, lacks the strength required for metallurgical coke and is extraordinarily low in ash.

Neither petroleum coke nor gas-house coke is adapted to metallurgical purposes, the use that consumes the great bulk of all the coke produced. Practically, therefore, the coke trade is concerned only with beehive and by-product coke. Although their product is interchangeable, the differences between the beehive and by-product industries are fundamental.

The accompanying table gives the value of motor benzol produced in the United States in 1923.—F. G. Tryon and H. L. Bennit in Mineral Resources of the United States for 1923.

MOTOR BENZOL PRODUCED IN THE UNITED STATES IN 1923, BY STATES

State	Production, Gal.	Total Value	Average Value per Gallon
Alabama	9,059,094	$1,431,140	$0.156
Colorado	1,295,367	[1]	[1]
Illinois	4,916,574	773,779	0.159
Indiana	12,267,075	1,889,727	0.159
Maryland	1,538,588	[1]	[1]
Michigan	1,214,469	331,498	0.273
Minnesota	752,792	144,480	0.205
New York	8,780,846	1,423,117	0.163
Ohio	13,580,719	2,281,454	0.167
Pennsylvania	24,315,545	3,914,453	0.161
Tennessee	375,670	54,357	0.145
West Virginia	2,371,144	435,601	0.175
Undistributed		466,227	0.155
	80,467,883	$13,145,833	$0.163

[1] Included under "Undistributed."

Viscosity and the Conradson Carbon-Residues of Lubricating-Oils

By GEORGE W. BURKE[1]

Illustrated with CHARTS

ABSTRACT

THIS paper deals with the relationship between the viscosity and Conradson carbon-residues of lubricating-oils for internal-combustion engines. Several curves are established using many grades of the same brands of oil while others are constructed to show this relationship with oils representing everything on the market.

Evidence is presented indicating that a true relationship does not exist between the viscosity at any temperature and the carbon-residue value, and sufficient data are presented to show in a general way what can be expected as to the carbon-residue value when the viscosity is known. Limitations are drawn showing which oils can be considered as being, from a carbon-residue standpoint, representative of good commercial products and further, those which have been subjected to drastic refining can be selected.

IT has been suggested[2] that the Conradson carbon-residue of a lubricating-oil is directly related to the viscosity at 212 deg. fahr. It is a very common occurrence to hear those who have tested oil samples say that the carbon residue increases proportionally with the viscosity. It is logical to assume such a statement to be true when one considers the chemical constitution of the more viscous oils, inasmuch as greater complexity of the molecule is encountered in the higher series of which greater viscosity is typical.

The availability of complete tests of several grades of many brands of oil that are generally sold throughout the United States made it possible to study the relation between these two characteristics. In Figs. 1 and 2 are presented in graphical form the relation of Conradson carbon-residue and Saybolt viscosity in seconds at both 100 and 210 deg. fahr. The various points on the same curve represent different grades of the same brand of oil.

By referring to Fig. 1, it will be noted, in general, that oils of the lower viscosities show carbon residues the value of which are similar but, as the viscosity increases, the divergence becomes more marked.

In Fig. 2, it will be observed that, at the higher temperatures, the curves are closer together at the lower viscosities.

It is obvious from Figs. 1 and 2 that the carbon residue, in a general way, increases with the viscosity at both the low and the high temperatures. In some cases, this increase seems to be almost proportional; but it is apparent that such cases are the exception. In general, inasmuch as the area covered by the curves is so great, the nature of the distribution of the curves would indicate positively that the Conradson carbon-residue does not increase proportionally with the viscosity at either 100 or 210 deg. fahr. It would be out of the question to construct a curve to which all oils would conform.

At this time it would be well to mention the fact that,

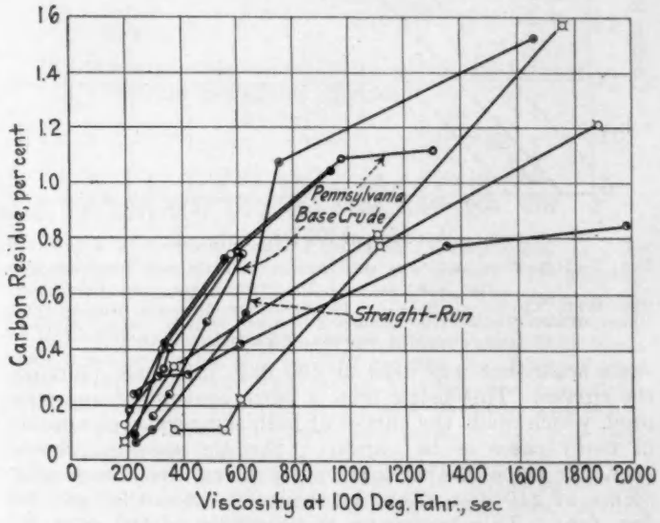

FIG. 1—RELATION BETWEEN THE CONRADSON CARBON-RESIDUE AND THE VISCOSITY AT 100 DEG. FAHR.

Two of the Oils Are from Pennsylvania Base Crude and Another Is a So-Called Straight-Run Material. The Various Points on the Same Curve Represent Different Grades of the Same Brand of Oil

probably due to the treatment, blending and the like that are resorted to in order to obtain values for viscosity which conform to certain specifications, factors are introduced that tend to make the curves more divergent at the higher viscosities.

It is interesting to note that the curves obtained for the same oils, when using the viscosities of 210 deg. fahr., are generally the same as those which were obtained from using the viscosities of the lower temperature, 100 deg. fahr. At 210 deg. fahr., inasmuch as the viscosity values are so small, it would be impossible to employ the

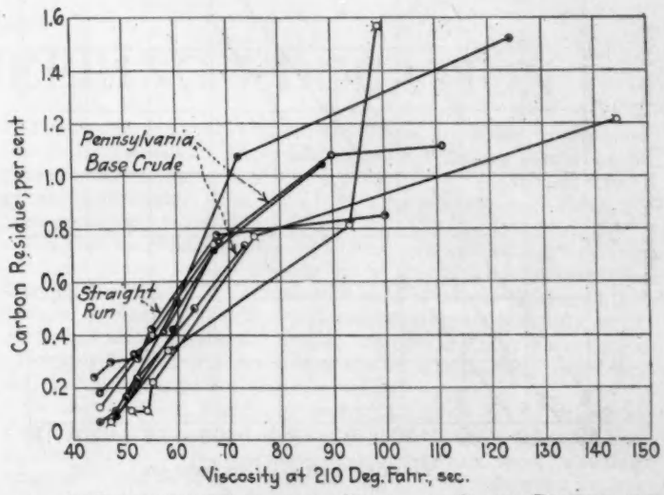

FIG. 2—RELATION BETWEEN THE CONRADSON CARBON-RESIDUE AND THE VISCOSITY AT 210 DEG. FAHR.

The Oils for Which the Curves Are Drawn Are the Same as Those of Fig. 1

[1] Chemical engineer, Iowa State College Engineering Experiment Station, Ames, Iowa.

[2] See *Journal of the American Society of Naval Engineers*, February, 1920, p. 56.

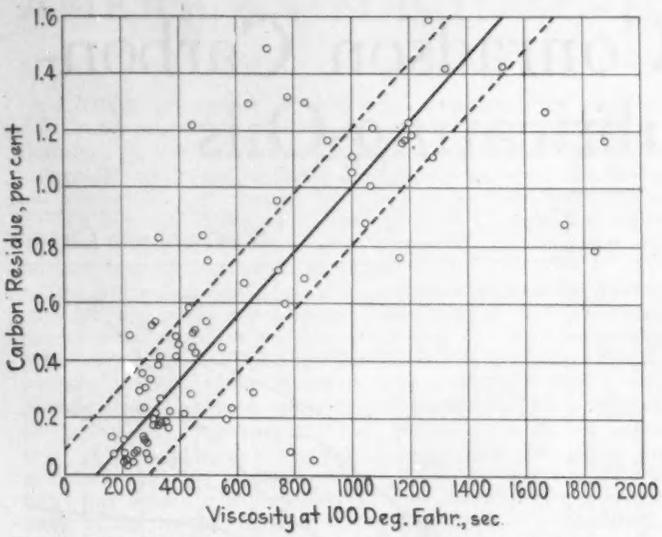

FIG. 3—RELATION BETWEEN THE CONRADSON CARBON-RESIDUE AND THE VISCOSITY AT 100 DEG. FAHR.
The Wide Variation Existing Is Strikingly Brought Out by the Chart Which Shows the Results Obtained with a Large Number of Oils, Only One Sample of Each Being Used

same scale that was used at 100 deg. fahr., for plotting the curves. This being true, a more convenient one was used, which made the curves at both temperatures appear in many cases to be parallel. Strictly speaking, however, the slope of the lines representing the curves and points at 210 deg. fahr., is about 20 times that at 100 deg. fahr. This brings up the question of the relation between the viscosities at 100 and at 210 deg. fahr.

The viscosities of 92 samples, taken at 100 and at 210 deg. fahr., were plotted against one another. It was found that 85 per cent of the points lay between lines that can be represented by the equations, $Y = 0.051X + 39$, for the top limit, and $Y = 0.034X + 35$, for the lower limit, where Y equals the viscosity at 210 deg. fahr., and X, the viscosity at 100 deg. fahr. Twelve per cent of the points lay above this area and 3 per cent below. A line bisecting the angle formed by the two lines can be represented by the equation, $Y = 0.043X + 36$. It is assumed, therefore, that, roughly speaking, the viscosities of oils at the temperatures under consideration are related in accordance with the above equation. Figs. 1 and 2 indicate plainly that oils having viscosities of 200 at 100 deg. fahr., have viscosities of about 45 at 210 deg. fahr. Using the above equation and solving for the viscosity at 210 deg. fahr., of an oil having a viscosity of 200 at 100 deg. fahr., we get a value of 44.6.

Fig. 3 represents very well what a wide variation exists between the factors under consideration, when a large number of samples representing everything on the market are used. The distribution of these points positively emphasizes the fact that, considering as a whole the lubricating-oils found on the market, it is impossible to associate mathematically carbon residue with viscosity. It might be possible, however, to prepare samples that would conform to a fixed rule; but such an occurrence will not become general and conform to everything being sold to the public.

In the case shown in Fig. 3, the wide distribution is also true in the same general manner. The straight solid lines in Figs. 3 and 4 represent roughly the average of all the points. It is evident that many of the values for carbon residue vary several hundred per cent from the average. This is true all along the line. It will be noted that, in Fig. 2, the line passes through carbon values of 0.1 and 1.0 per cent at the viscosities of 200 and 1000 respectively. In Fig. 4, the average passes through carbon values of 0.1 and 1.5 per cent at viscosities of 48 and 100 respectively. If we draw lines parallel to those representing the average in both cases, 100 and 210 deg. fahr., at distances representing 0.2 per cent, it will be observed that, in both instances, about 70 per cent of all the points are between these lines. This being true, it seems fair, therefore, to assume that such an average as is indicated by the space between these lines would represent fairly well what could be expected in a very general way of commercial oils with regard to the relation between the viscosity and the carbon residue.

TABLE 1—RELATION OF CONRADSON CARBON-RESIDUE, COLOR AND VISCOSITY

Carbon Residue, Per Cent	Relative Color	Viscosity at 100 Deg. Fahr., Saybolt Sec.
0.07	189	244
0.17	278	315
0.17	285	316
0.17	535	281
0.19	590	560
0.32	580	295
0.68	1,200	842
0.74	1,042	502
0.82	245	330
1.79	3,420	1,995

[3] See *Journal of the American Society of Naval Engineers*, February, 1920, p. 56.

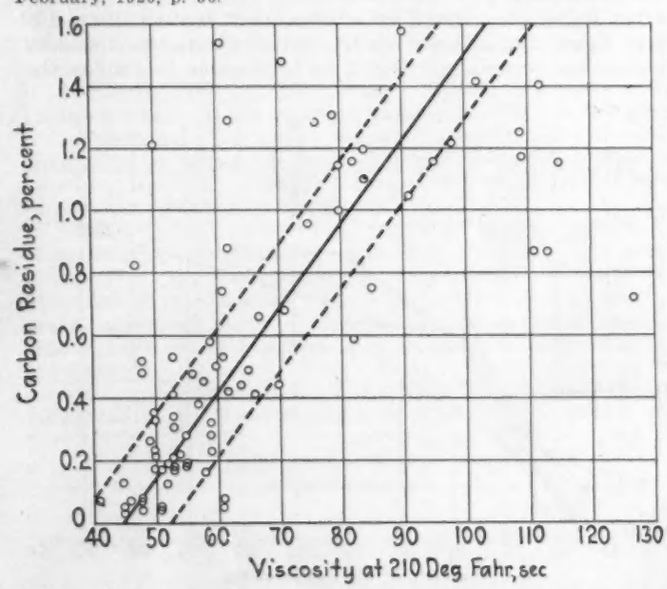

FIG. 4—RELATION BETWEEN THE CONRADSON CARBON-RESIDUE AND THE VISCOSITY AT 210 DEG. FAHR.
This Chart Also Shows the Wide Variation That Was Brought Out in Fig. 3. As in the Other Case, the Results Are All for Single Samples of a Large Number of Oils

It will be observed that, in both cases, at 100 and at 210 deg. fahr., about 85 per cent of all points lie below the upper limit of the average zone. This being the case, it would seem that oils the viscosity-to-carbon-residue relation of which lies below the upper limit of the average zone are representative of the better grades of oil to be found on the market.

It has been understood that drastic refining produces oil of low carbon-residue. This being the case, it would follow naturally that oils having relatively low carbon-residues at the higher viscosities are those in which refining has been carried out to an extent that would indicate a better product, from which the best results should be obtained. It has been suggested[3] that the Conradson carbon-residue value of an oil is an indication of the quantity of carbon deposit to be found in the

engine. If such is true, excellent results should be obtained, other conditions being normal, by the use of those oils the carbon-residue values of which lie below the average, as is indicated in Figs. 3 and 4.

Flowers, McBerty and Reamer[4] state that any desired color and carbon residue can be obtained by using enough decolorizing earth during the refining process. It should not, however, be understood that color has a direct bearing on the carbon-residue value. Table 1 indicates that, generally speaking, the assumption can be made that oils light in color have relatively low carbon-residue values and vice versa.

Table 1 indicates that, in a very general way, a relation exists between the carbon residue and the color, but that is not to be depended upon.

[4] See *Industrial and Engineering Chemistry*, May, 1925, p. 484.

Conclusions

(1) Considering commercial lubricating-oils as a whole, there does not exist any particular fixed relation between Conradson carbon-residue and viscosity

(2) It is possible to obtain oils of relatively high viscosity having low carbon-residue values

(3) Oils showing a low viscosity-to-carbon-residue relation should cause less carbon deposit in the engine

(4) When possible, low-viscosity oils should be used in internal-combustion engines

GOLD PRODUCTION AND ECONOMICS

UNLIKE most commodities, the yearly production of gold is small in comparison with supplies of the metal on hand. The total monetary stock of gold in the world is the equivalent of more than 2 decades' output. Therefore year-to-year fluctuations in gold production, even when large, do not normally have a marked effect on the immediate financial situation or on current prices of commodities. This is, of course essential to its use as a standard of value.

Over a period new supplies largely determine the rate of growth of the reserves upon which the superstructure of credit rests. They have, therefore, a direct influence on the drift of prices. And this drift affects investment and financial policy no less profoundly than it does the fortunes of the producers of commodities. With the drop in commodity prices since 1920 gold's purchasing power has been somewhat increased, but it is still less than half that of the period from 1890 to 1899.

By no means all the gold produced becomes available for monetary use. Of the world production of $19,500,000,000 since the discovery of America, monetary stocks were estimated to contain about $9,700,000,000 at the end of 1924. The difference is accounted for by losses, industrial consumption and the absorption of treasure in countries of the East, notably India.

In the last 3 decades, the world monetary stock has grown by about $5,600,000,000, while production has totaled $10,700,000,000. Roughly, one-half of the output has been absorbed by other than monetary uses. Since 1900 the net inflow of gold into India has been about $1,400,000,000; to this must be added India's own production of over $200,000,000, making a total absorption of perhaps $1,600,000,000, or over one-sixth of the world's output in the period. In general, industrial requirements for gold before the war were rising. It is not improbable that the trend of future demand will be upward. Indian takings average higher rather than lower than pre-war figures and in 1924 reached the unprecedented level of $200,000,000. The Indian holdings are unavailable for monetary use; the gold is not lost, however; and in the future, with changes in custom and taste, it may flow back into the international supply.

Summarizing, the rapid growth of gold output up to 1915 far more than offsets increased non-monetary uses. Before the war from $250,000,000 to $300,000,000 per year was apparently being poured into monetary employment. For the future the prospect seems somewhat different. World output may show moderate improvement over its present level for several years, but the likelihood of a resumption of the rapidly rising trend of the 3 decades ending with 1915 is small. Rather, the outlook is for stability of output with only moderate changes, in either direction, from the present level. It must, of course, be emphasized that this view is based on current conditions and production; that though the earth has been pretty well overrun by prospectors possibilities of important discoveries still exist and that for the longer future gradual betterment of communication and technique will doubtless make available reserves that cannot now be worked. But insofar as it can now be judged, future additions of gold to monetary stocks are likely to be considerably smaller than those to which the world had become habituated "before the war."—*Commerce Monthly.*

ECONOMICS IN ENGINEERING EDUCATION

IN an ideal conception of the engineering curriculum, economics would be ranked with the physical sciences as one of the foundations of engineering. The present formal treatment of the subject does not seem to be based on such a conception but rather that of a collateral subject of primarily cultural value. As long as this conception prevails, the provision of time for work in formal economics seems adequate, in most cases. If the treatment of the subject could be made to articulate more closely with the interests and problems of engineering, a more generous time allotment would be warranted.

Of business subjects, as such, accounting and business law seem to have the best claim for inclusion as required work. Granting that a more extended business training for engineers is much to be desired, that it must be provided for in the college curriculum does not follow. The room for doubt as to the scientific quality and general effectiveness of much of the collegiate instruction of this character is still so great as to make the sacrifice of scientific, technical and cultural work of well-proved value, in order to provide for it, inadvisable. Extended business training would seem properly to belong in a distinct program to be pursued after graduation, either in a school of business or as a form of post-scholastic training.

Greater emphasis on the economic aspects of engineering subjects proper seems clearly to be feasible and desirable. The need seems to be for not only limited modifications of the factual materials in these courses, dealing specifically with costs and other economic details, but also a closer association of economic and physical elements in engineering problems and in the criteria for their solution.

In my opinion, the most immediate step to be taken to qualify the engineer for larger responsibility in industry and public affairs is to increase his competency as a working economist and to win a wider recognition of this very important aspect of his work in the world today.—W. E. Wickenden in a report to the Society for the Promotion of Engineering Education.

THREE-LANE TWO-WAY ROADWAYS

IF the ideal movement of traffic is that which will permit each vehicle to travel continuously at its desired speed, but within the legal regulation limit, it is apparent that the traffic capacity of a two-lane roadway from this standpoint will be very low. Traffic capacity, considered from the viewpoint of the maximum number of vehicles that can pass a given point in a given period, far exceeds the capacity that has been termed ideal. For two-lane roadways, the actual traffic capacity varies within wide limits as it depends on many factors, including the width of roadway, the location of the lanes in which vehicles travel, the widths of the various vehicles, the speeds and distances apart at which vehicles travel, the number of vehicles traveling at each speed, the kind and number of vehicles traveling in groups, retardation points, and the relative volume and character of traffic in each direction.

Investigations indicate that the 20-ft. roadway is of ample width to provide adequate clearances between the sides of vehicles and the edges of the roadway and between passing vehicles. On one roadway under investigation, where the maximum hourly traffic was 750 vehicles, the clearance between vehicles was from 3 to 4 ft. No instances of three vehicles being abreast were noted. As the average width of three automobiles is 16½ ft., it is evident that the clearances between the vehicles and between the vehicles and the edges of the roadway would not be satisfactory. The committee concludes that 22 and 24-ft. roadways are not required for two lanes of traffic.

Roadways between 24 and 30 ft. in width usually have middle lanes which encourage utilization. On 24-ft. roadways, the Bureau of Public Roads found that the average clearance between automobiles was 6.1 ft. and between trucks, 5.1 ft. In another investigation of a roadway of this width, having a maximum hourly traffic of 1250 vehicles, the clearance between automobiles was found to vary from 5 to 5½ ft. and between trucks from 4 to 6 ft. At the point of observation, it was noted that three vehicles were abreast from one to seven times per hour, in each case all the vehicles being automobiles. Considering that the average width of an automobile is 5½ ft., the natural conclusion agrees with observations, namely, that the vehicle occupying the middle lane forced its passage between the other two vehicles. Generally fast and reckless drivers constituted the majority of operators who endeavored to use the middle lane.

On a 30-ft. roadway, having a maximum hourly traffic of 1050 vehicles, the clearance between automobiles was found to vary from 8 to 10 ft. and between motor trucks from 5 to 9 ft. At the point of observation, three vehicles were abreast 7 to 21 times per hour. It is evident that the middle lane of a 30-ft. roadway is very generally utilized.

The illustrative data submitted indicate that roadways of from 24 to 30 ft. in width are used as three-lane two-way roadways. Unfortunately, however, traffic movements on the middle lane cannot be governed by a right-of-way regulation. Hence the use of three-lane roadways provides conditions under which accidents may frequently occur. The committee, therefore, from the standpoint of encouraging design that will promote the safe utilization of highways, recommends the use of the four-lane roadway when the highway transport survey indicates that the traffic capacity of a two-lane two-way roadway will be exceeded.—From Committee Report to Highway Research Board by Chairman G. E. Hamlin, Connecticut State Highway Commission.

POST-SCHOLASTIC ENGINEERING TRAINING

NO college is called upon to turn out an all-round engineer. College training must provide the common base, with whatever distinctive foundations are needed for subsequent specialization, but the superstructure of specialized training for the most part must come with experience. Experience alone, as a basis for specialization, promises to be inadequate. What is needed is education with practice. The cooperative plan is a distinct step in that direction, good as far as it goes, but the parallel training is carried only through the rudimentary stages of experience and does not extend into the advanced realms of professional specialization.

The rational simplification of college programs does not call for the abandonment of any needful training, but its postponement, which means graduate work for a selected minority and definite post-scholastic education for the majority. To conceive of the undergraduate curriculum as a terminal program of education or one to be completed through experience alone is a mistake.

Two distinct needs are to be met in a program of post-scholastic education. One is for a broader business training than can be provided for in the curriculum, and the other is for specialized technical training to accompany experience. If such an organized stage of education is to be introduced widely, it will call for elaborate developments in extension methods of instruction. From many points of view that the colleges should meet this problem jointly, rather than singly, seems desirable. To set up an adequate system of post-scholastic training, combining business training, specialized technical training and related introductory experience, to integrate these elements into a true professional novitiate equivalent to the interneship of the physician, to relate such training to the award of professional degrees on one hand and to the terms of admission to professional grades of membership in engineering societies on the other, to make such training widely available to graduates on even terms, and to make it normally obligatory upon them would call for large-scale teamwork by the colleges, the industries and the major professional organizations. If any such development is to come, that the initiative should come from the colleges and that they should provide in their own organization for the nucleus around which the needed organization may be created seems eminently desirable.

Parallel to the need for organized post-scholastic training is that for resident graduate work. While half the engineering colleges have graduate departments on paper, probably not more than 40 or 50 are able to provide work of adequate merit, and probably not more than 20 at the most are able to offer a wide range of graduate work of high quality. We feel convinced that nothing could be more unfortunate than a movement toward inflation. Graduate work ought to be more than an additional period of undergraduate work under a more pretentious name. At its best it is a personal discipleship in which the student ought to seek out the best qualified master. In most cases this ought to mean a migration to some institution other than the one attended as an undergraduate. Institutions will do well to specialize and acquire a distinctive individuality in this realm of work. If these principles are intelligently guarded, we are probably safe from inflation, but if graduate work becomes a formal program to be promoted for institutional aggrandizement, it is time to hoist the danger signals.—W. E. Wickenden in a report to the Society for the Promotion of Engineering Education.

A Roots-Type Aircraft-Engine Supercharger

By ARTHUR W. GARDINER[1]

DAYTON SECTION PAPER *Illustrated with* DRAWINGS, CHARTS AND PHOTOGRAPHS

ABSTRACT

DEVELOPMENT of the aircraft powerplant has been the greatest single contributing factor to the progress of aviation. Further successful utilization of the conventional airplane will be dependent upon further improvements in the powerplant. As the weight of the conventional four-cycle aviation engine can hardly be expected to be reduced materially without sacrifice of durability, a logical field for future development seems to be the improvement of its altitude performance. Power developed by the engine is directly proportional to the weight of the charge burned in the cylinder, if other conditions are constant; therefore, the power developed at altitude, for a constant engine-speed, will decrease approximately in direct proportion with the decreased air-density, and at 20,000 ft. will be less than one-half the power developed at sea-level. Of several proposed methods of improving engine performance at altitude, supercharging is unquestionably superior, on the basis of power output.

Attention has been directed, heretofore, toward developing the high-speed centrifugal-type air-compressor and, so far as is known by the author, no information has been published on the use of the positive-displacement rotary-type compressor as an aircraft-engine supercharger. In 1918 the Sub-Committee on Powerplants for Aircraft of the National Advisory Committee for Aeronautics recommended that the Roots-type compressor be investigated; consequently, an analysis of the characteristics of this type was made by the Clark Thomson Research, at the request of the Committee, and complete design-analyses and drawings for an experimental supercharger were submitted in October, 1919. A complete supercharger was then built and sent to the Langley Field laboratory for test.

The design, principles of operation and characteristics of the Roots-type compressor are described, and its slip-speed due to air leakage past the rotors, its pulsating discharge, type efficiency, and variation in torque are discussed. The Roots-type supercharger built for the National Advisory Committee for Aeronautics, as designed for use with the Liberty-12 engine, is described and illustrated. This differs from existing commercial compressors of this type, as it must be a relatively high-speed small-volume machine of light weight and yet rugged.

The set-up for laboratory tests is illustrated and described and the results of the tests are presented in charts, which show the effect of compression and rotor-speed on the volumetric efficiency, the weight of air delivered and the power required by the supercharger at various rotor-speeds, the adiabatic efficiency, effect on volumetric efficiency of reducing the length of the rotors, and the power required by the supercharger at altitude by (*a*) varying the supercharger speed, (*b*) maintaining constant supercharger-speed and bypassing the excess air at low altitudes and (*c*) throttling the supercharger inlet. Minimum power at low altitudes is obtained by method (*a*) but this ideal method is difficult of attainment. An approach to this ideal is attained by method (*b*) and as the air is compressed to the same extent in both cases at any given altitude, the temperature of the air supplied to the engine is the same and the minimum.

Attempts to synchronize the pulsations of the supercharger with the engine induction-periods did not measurably increase the engine-power, due perhaps to the uneven induction-timing of the Liberty-12 engine.

For flight tests the supercharger was installed with a Liberty-12 engine in a modified DeHaviland-4 airplane, and an air-scoop on the side of the fuselage was connected with the supercharger intake. A small booster water-cooler in series with the main radiator was found necessary when maintaining full supercharging to 20,000-ft. altitude and was installed underneath the fuselage. With full supercharging to 20,800 ft. and using the booster water-cooler, the indicated absolute ceiling was increased about 92 per cent and the service ceiling about 100 per cent as compared with the performance of an unsupercharged DeHaviland-4 observation airplane in a McCook Field test, and the time required to climb 15,000 ft. was reduced from 32 to 19 min. Although no air-cooler was used between supercharger and engine, the maximum carbureter air temperature at 20,000 ft. was only 140 deg. fahr.

The supercharger was also mounted with a Wright J-4 radial air-cooled engine in a UO-1 airplane and was geared-down to give full supercharging to 18,000 ft. Flight tests showed that the supercharger increased the absolute ceiling 66 per cent and the service ceiling 71 per cent, the carbureter air-temperature reached 160 deg. fahr. and the maximum temperature in the cylinder-heads was increased from 480 to 530 deg. fahr. The conclusion is reached, therefore, that an air-cooled engine having sufficient cooling capacity for operation under all conditions as a normal engine can be supercharged to moderate altitudes with a material gain in airplane performance and without developing excessive cylinder-temperatures.

Twelve reasons are given for the conclusion that the Roots-type compressor seems to be well adapted for use as an aircraft-engine supercharger for many service requirements. In opposition to the advantages enumerated, its bulk and weight are cited as disadvantages, although the supercharger described in the paper is not to be taken as an example of the possible ultimate reduction in size and weight.

IT can be stated, without fear of contradiction, that the greatest single contributing factor to the progress of aviation has been the development of the aircraft powerplant. Just as the first practicable flight of heavier-than-air machines was contingent upon the advent of a suitable powerplant, and as the progress of aviation from the status of a rather novel adventure to the position it now occupies as an accepted mode of transportation has largely centered upon and paralleled engine development, so, in the future, the further successful utilization of the conventional airplane will, to

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a no less extent, be dependent upon further improvements in the powerplant.

A brief review of aircraft-engine development will show that attention has been focused primarily upon the main problem of reducing the specific weight, by increasing the specific power-output and decreasing the weight of individual parts, as rapidly as has been shown to be practicable by experience gained through research in materials and careful attention to details of design. This required the utmost of engineering skill, at the same time, to improve the reliability and durability of the powerplant unit. An examination of some of the present-day engines would lead one to hazard the opinion that, in the light of current knowledge of materials, a further important reduction in the specific weight of conventional four-stroke-cycle engines is hardly to be expected without sacrificing durability. Therefore, with due regard for continued improvement along these lines and for the possible development of engine types that are radically different from the present accepted standards, it would seem that one of the most logical and profitable fields for future development of the aircraft engine would be the improvement of its altitude performance.

Considerable literature dealing with the altitude performance of the normal internal-combustion engine has been published, and it is not planned to discuss this phase of the problem herein. Suffice it to call attention to the fact that, as the power developed in the cylinders of the internal-combustion engine is directly proportional, other conditions being constant, to the weight of charge burned in a unit of time, it naturally follows that the power developed at altitude, for a constant engine-speed, will decrease approximately in direct proportion with the decreased air-density encountered; the brake, or effective, power decreasing somewhat more rapidly due to the fact that certain of the friction losses remain constant. Thus, an engine will develop somewhat less than one-half its sea-level power under altitude conditions of one-half air-density, or at an altitude about 20,000 ft.

Each of the several projected methods for improving engine performance at altitude has certain advantages and disadvantages when applied in service, which fact renders it difficult to establish limits of practicable usefulness for each. However, it seems that each of the proposed methods would have a particular service application, depending primarily upon the operation-altitude of the airplane under consideration and the service requirement at that altitude, be it long-distance cruising or merely superior performance. Other criteria in making the selection would be based on (*a*) consideration of engine-operating conditions, as affecting the stresses and working conditions for the various engine parts, which in turn affect the engine reliability and durability; (*b*) increased weight and complication of the powerplant unit; (*c*) reliability of the combined powerplant unit; (*d*) special fuel-requirements as affected by the detonation tendency; and (*e*) fuel economy under the conditions of flight.

Supercharging Maintains Power at Altitude

All of the methods proposed have for their purpose an improvement of the power output at altitude relative to the normal performance of the engine, but can effect that function only in varying degrees over the full range of altitude operation of the airplane. On the basis of power developed at high altitude, supercharging, as defined by the maintenance of sea-level density of the air supplied to the engine, unquestionably is superior to the other methods. Whatever may be the particular advantages of supercharging, it would seem to have a definite application in the future development of aircraft engines; and we are concerned in this paper with a discussion of the characteristics and merits of a given type of air-compressor used to effect the supercharging of a normal engine.

In reviewing the supercharger developments[2] it will be noted that attention for the most part has been directed toward developing the high-speed centrifugal-type air-compressor, whereas very little consideration has been given to the positive displacement rotary-type compressor, although it possesses certain advantages for supercharging service. The Roots compressor, belonging to the latter class, has been used to some extent as a supercharger on automobile engines, notably on the Mercedes automobile engines[3], and on racing engines in Europe and in this Country. Insofar as is known, however, no information has been published dealing with its use as an aircraft-engine supercharger. The Zoller sliding-vane-type compressor, also of this general class, has been used in Europe on automobile engines and, it is reported, on a two-cycle aircraft engine built by the same company.

In 1918 the importance of supercharger development was brought to the attention of the National Advisory Committee for Aeronautics by its Sub-Committee on Powerplants for Aircraft, with the recommendation that

[2] See The Journal, February, 1926, p. 185.
[3] See The Journal, May, 1926, p. 516.

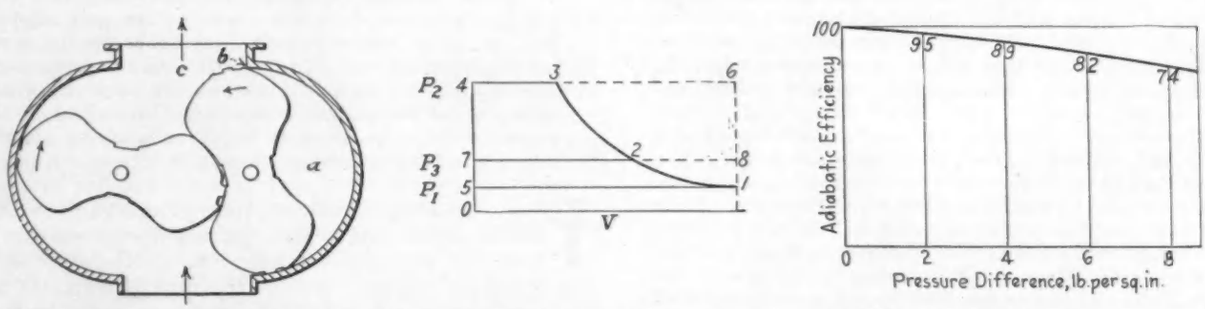

Fig. 1—Section through Roots-Type Compressor, Its Pressure-Volume Relations and Its Adiabatic Efficiency

A Definite Volume of Air, *a*, in the Drawing at the Left, Is Transferred from the Inlet Side to the Discharge Side when the Upper Tip of the Right-Hand Rotor Passes Point *b*, and the Lower Tip Simultaneously Closes the Intake. Trapped Air *a* Is Then Suddenly Compressed by Back-Pressure of Previously Discharged Air *c*. Further Movement of the Rotor Is Resisted by the Full Discharge-Pressure, Which Establishes the Volume-Pressure Relations as a Rectangular Card, as in the Chart at the Center. The Type Efficiency of the Roots Compressor Decreases as the Amount of Compression Increases, the Extra Work Done by the Roots Compressor as Compared with True Adiabatic Compression Being Represented by the Difference in Area of the Two Cards. The Decrease in Compression Efficiency for the Roots Compressor Is Shown in the Chart at the Right, in Which the Values Given Are Approximate for the Case in Which the Discharge-Pressure Is Maintained at 1 Atmosphere

the Roots-type supercharger be investigated. This recommendation was the result of an investigation of the supercharger problem, which showed that at this time the Roots-type positive-displacement rotary compressor held the greatest promise, provided that the size and weight could be reduced to meet aviation requirements and provided further that the supercharger could be operated at high speeds and that the pulsating type of discharge would not prove detrimental to good engine-operation. Consequently, at the request of the Committee, a preliminary analysis of the characteristics of the Roots compressor was made by the Clark Thomson Research, which has put its facilities at the disposal of the government, and George W. Lewis, engineer-in-charge, submitted to the Committee in October, 1919, a report with complete design-analysis and drawings for an experimental supercharger, following which one supercharger was built and sent to the Langley Field laboratory for test. Since that time, its characteristics have been investigated both in the laboratory and during flight on several types of airplanes.

How the Roots-Type Compressor Functions

The Roots-type of compressor was invented so long ago that it is difficult to associate its present name with that of the inventor. It probably derives its name from the fact that it was first developed commercially by the P. H. & F. M. Roots Co., of Connersville, Ind., in 1859. Also, there is reference to a blower of this type having been exhibited at the Paris Exposition by one Elihu Root in 1867.

Following its development for commercial use, it has been used, both for handling liquids and compressing air, in that type of service where it was required to deliver relatively large volumes against moderate pressure-heads, the economical range, as regards delivery pressures, being arbitrarily set at from 8 oz. to 8 lb. per sq. in. Below 8 oz. the centrifugal type is usually employed, and above 8 lb. the reciprocating pump or compressor is regarded as the more economical for the reason that leakage in the Roots type increases and, when handling air, the compression efficiency decreases with an increase in delivery pressure. The commercial compressors, or blowers, usually are operated at rotor-speeds up to 800 r.p.m., depending on the size, with the maximum speed of probably 850 r.p.m.

The Roots blower is of the type generally known as the positive-displacement rotary, and consists essentially of two rotors, having two lobes each, which are rotated in opposite directions at the same speed within a case composed of two halves of a cylinder separated by the center-distance between the rotors (see Fig. 1). The lobes of one rotor fit into the recesses in the mating rotor and are held in correct phase-relation by timing-gears located at one end of the rotor shafts. Clearances are maintained at all points between the rotors and between the rotors and the case, to avoid internal friction and assist in obtaining high mechanical efficiency. The contour of the rotors, which are usually hollow metal-castings, is made up of sections of epicycloid and hypocycloid curves, and thus, being mathematically correct for proper mesh, the clearances can be made uniform and small. The rotors are mounted on separate shafts, one of which takes the main drive; the other is driven through the timing-gears. These shafts usually are carried in plain bearings.

As this compressor operates with clearances, it is evident that leakage will increase with increase in compression. The amount of leakage is measured usually in terms of the rotor-speed required to maintain a given pressure with no delivery, and the speed so obtained is termed the slip-speed. To determine this, the discharge from the compressor is blocked-off, in which case the slip-speed will vary with compression as the square root of the pressure-difference between intake and discharge. The amount of leakage, or slip, is a function of the pressure-difference and the clearance area, but, as the clearance area is at all times exposed to the full pressure-difference, the amount of leakage is independent of the speed of operation of the rotors in service. As the total volume handled per revolution varies as the cube of a linear dimension and as the length of the slip-path varies directly as a linear dimension, it is apparent that the ratio of the leakage-volume to the total volume will increase as the size of the compressor is decreased. Thus, for large commercial blowers of 300-cu. ft. displacement per revolution, the slip-speed at 1-lb. pressure-difference is usually from 3 to 5 r.p.m., whereas, with smaller blowers of 0.75-cu. ft. displacement per revolution, the slip-speed, at the same pressure-difference, will be about 65 r.p.m. If taken with the intake instead of the dis-

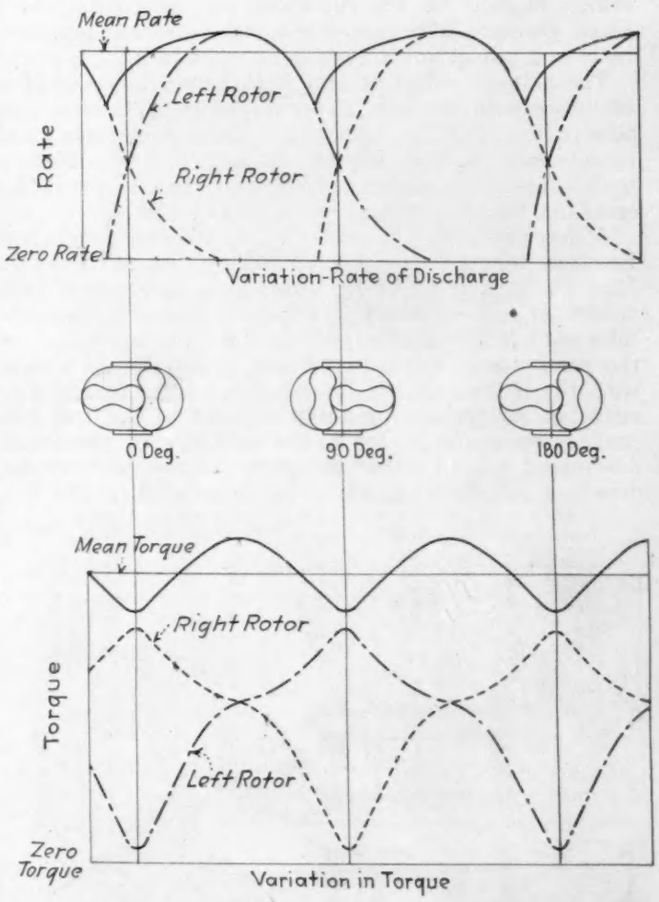

Fig. 2—Variation in Rate of Discharge and in Torque of Roots Compressor

Curves in the Charts Are Drawn for the Roots Supercharger Built for the National Advisory Committee for Aeronautics. The Discharge Is Continuous but at a Non-Uniform Rate, as Shown by the Curved Solid Line in the Upper Chart, and the Combined Rate of Delivery for Both Rotors Varies Appreciably from the Mean Delivery Rate. Increase in the Rotor-Speed, for a Given Compression, Increases This Variation. Pressure-Pulsations Are Set-up in the Discharge-Line by the Non-Uniform Rate of Delivery, and the Amplitude of the Pulsations Increases with Increase in Compression and Speed. Variation in the Torque Required To Turn the Rotors through One Revolution Is Shown by the Curves in the Lower Group. This Is Due to the Unbalanced Areas of the Rotors when in Different Positions. Maximum Torque Occurs When the Rotors Are Parallel and 45 Deg. from the Vertical. The Combined Torque for Both Rotors Varies from 86 to 111 Per Cent of the Mean Torque

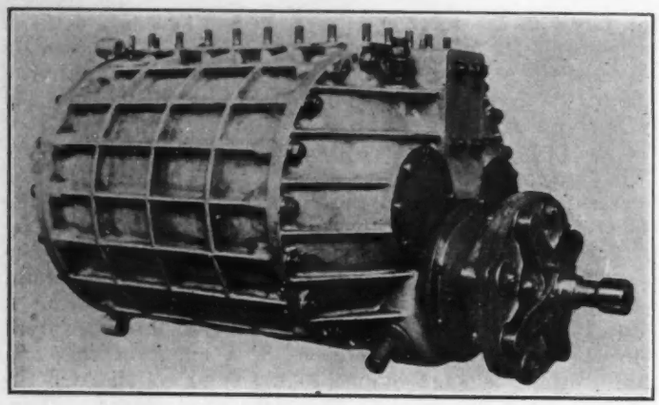

FIG. 3—ROOTS-TYPE SUPERCHARGER BUILT FOR THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

This Is Shown with a Flexible Coupling for Separate Mounting. The Weight Is 88 Lb. The Rotors Are 11 In. Long and 9½ In. in Diameter. The Over-All Width Is 17 In. and the Over-All Length from the Rear of the Engine Is 19 In. Deep Ribbing on the Side Housings Gives Rigidity and Assures the Maintenance of Small Clearances of the Rotors

charge blocked off, the slip-speed will be greater for a given pressure-difference, due to the increased pressure-ratio and reduction in density at the intake.

The primary effect of slip is to lower the volumetric efficiency with increase in compression. There is also a secondary effect, in that the leakage of compressed, and consequently heated, air to the intake side, which is then subject to further compression, results in an increase in the temperature of the discharged air.

A description of the cycle for air-compression in the Roots compressor can best be followed by referring to Fig. 1. The action of the rotor is to transfer a fixed volume of air, *a*, in the drawing at the left, from the inlet side to the discharge side. As the upper tip of the rotor passes the point *b*, and practically coincident with the closing of the intake, the volume of air *a* is suddenly compressed by being exposed to the full discharge-pressure at *c*, due to the back-flow of previously discharged air. Further movement of the rotor in the direction indicated by the arrow is resisted by the full

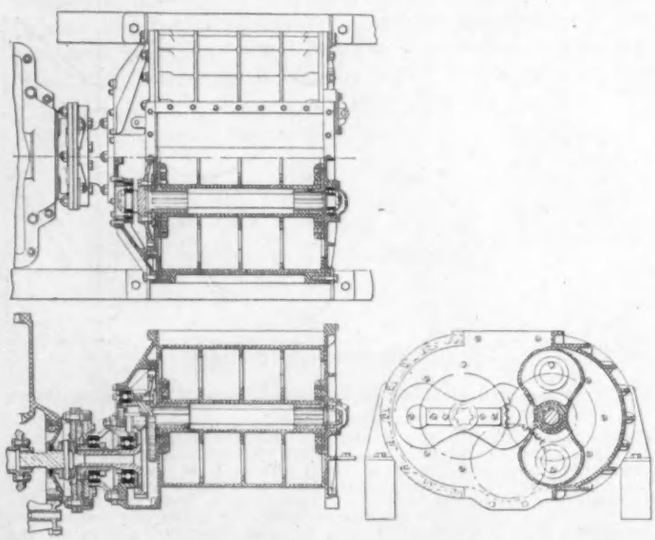

FIG. 4—SECTIONS THROUGH ROOTS-TYPE SUPERCHARGER MOUNTED WITH LIBERTY-12 ENGINE

The Rotors Are Hollow Castings and Are Driven by Splined Hubs on Their Shafts. Transverse Ribs Prevent Distortion of the Rotors at High Speed. A Taper Pin in the Coupling Is Designed To Shear when Subjected to Excessive Torque and Thereby Permit Uninterrupted Engine-Operation in Event of Failure of the Supercharger

discharge-pressure, which establishes the pressure-volume relations as a rectangular card, or what is commonly known as the hydraulic or pump cycle. The work per cycle is thus represented by the product of quantity and pressure-difference.

COMPRESSION EFFICIENCY AND DELIVERY RATE

Due to the fact that the Roots compressor operates on the hydraulic cycle, it can be seen readily from the illustration that its type efficiency, as represented by the ratio of the area of the adiabatic card for compression and delivery of the same volume of air to the rectangular card for the Roots, decreases as the amount of compression increases, the difference in area of the two cards representing the extra work done in the Roots compressor. The decrease in compression-efficiency for the Roots compressor, referred to the adiabatic standard, is shown at the right of the illustration, the values given being approximate for the case in which the discharge-pressure is maintained at one atmosphere.

The Roots compressor gives a continuous but non-uniform rate of delivery, as represented by the upper curves of Fig. 2. These curves, which show the rate of delivery for each rotor and the combined rate for both rotors, with no compression, are drawn for the Roots supercharger developed for the National Advisory Committee for Aeronautics, the rotors of which are not full cycloidal in contour. Rate-of-delivery curves for full-cycloidal rotors would be similar. It will be noted that the combined rate of delivery for both rotors varies appreciably from the mean delivery-rate. For a given rotor-speed, this variation from the mean rate of delivery will increase with increase in compression, as the maximum rate will remain practically constant, whereas the minimum rate will decrease owing to the increase in the amount of back-flow required to effect compression. Likewise, since the maximum rate of delivery increases proportionately with increase in speed and since the minimum rate of delivery will not increase in the same ratio, due to the rate of back-flow being independent of rotor-speed, it is evident that increasing the rotor-speed, for a given compression, results in an increase in the variation from the mean delivery-rate.

Due to the non-uniform rate of delivery, it is obvious that pressure-pulsations will be set up in the discharge-line from the compressor, and the amplitude of these pulsations will increase with increase in compression and, within limits, with increase in speed. The magnitude of the pressure-pulsations will reach the maximum, for given conditions of rotor-speed and compression, when they synchronize in period with the natural period of vibration of the column of air in the discharge-line, resulting in a condition of resonance, in which case the magnitude is limited only by the amount of the friction-damping in the discharge-line.

Considerable variation exists in the torque required to turn the rotors of the Roots compressor throughout one revolution due to a variation in the amount of the unbalanced areas with the rotors viewed in different positions. With the rotor in a horizontal position, there is practically complete pressure-balance on either side of the rotor axis, whereas the maximum amount of unbalance occurs with the rotor in the vertical position. The lower curves of Fig. 2 show the variation in torque for one rotor and variation in the combined torque for both rotors of the National Advisory Committee for Aeronautics supercharger. The torque for one rotor varies from the minimum of 5 to the maximum of 80 per cent of the mean torque, and the combined torque

for both rotors varies from 86 to 111 per cent of the mean, the maximum torque occurring when both rotors are parallel and 45 deg. from the vertical. The special contour of the supercharger rotors prevents obtaining complete balance for one rotor when in the horizontal position.

Roots Supercharger for Liberty-12 Engine

At the time the Roots compressor was under consideration for use as an aircraft-engine supercharger, it was recognized that for this service its design and operating speed must of necessity be radically different from those of existing commercial machines. In the first place, it was required that the supercharger be a relatively high-speed small-volume machine to handle the required volume of air and still come within the space and weight requirements for use in airplanes. In this connection, little was known of the discharge characteristics of the Roots-type compressor when operated at high speeds, as information was limited to brief tests of commercial compressors operated over a very limited range of speeds; and it was thought that operation at more than

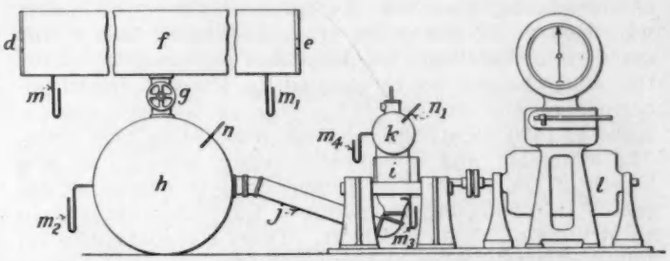

Fig. 6—Diagrammatic Arrangement of Apparatus for Laboratory Tests of the Supercharger

Air Is Drawn through Orifices *d* and *e* in the Orifice Box *f*, and the Pressure-Drop Is Measured To Obtain the Air-Weight. The Air Passes through a Regulating Valve, *g*, into the Depression-Tank *h*, in Which the Amount of Depression Is Governed by the Regulating Valve and Varied To Simulate Altitude Pressure-Conditions for the Supercharger *i*, to Which the Air Passes through a Large Pipe, *j*. The Supercharger Discharges into an Open Receiving-Tank, *k*, and Thence into the Atmosphere. An Electric Cradle-Dynamometer, *l*, Drives the Supercharger, and the Power Is Measured by the Usual Torque-Scale and Revolution Counter. Mercury Manometers *m*, m_1, m_2, m_3, and m_4 and Thermometers *n* and n_1 Are Placed as Shown

sibly be increased by synchronizing the pressure-pulsations from the supercharger with the induction-periods

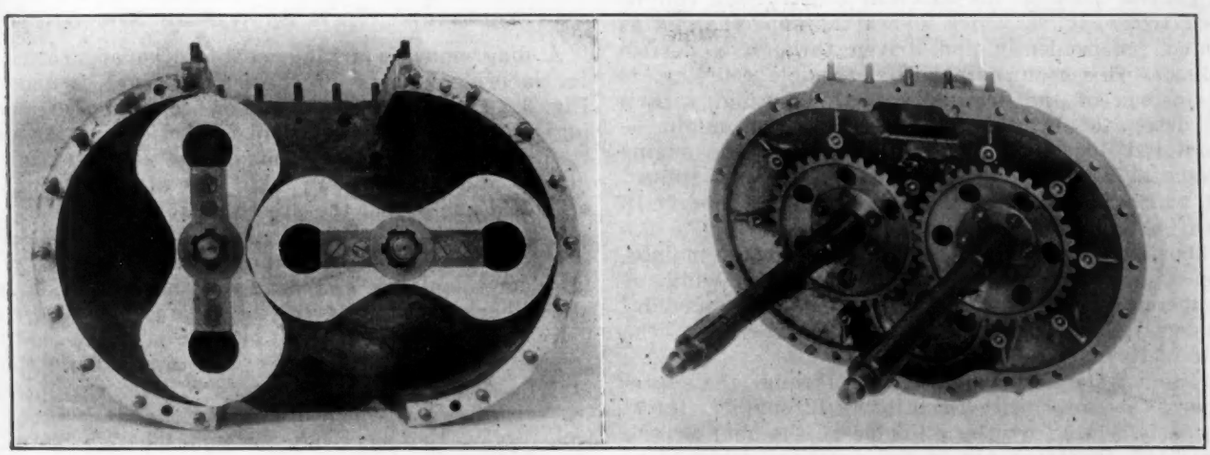

Fig. 5—Interior of the Supercharger and the Rotor Drivin g-Gears and Shafts

Note the Mesh of the Rotors and Their Contour, Which Differs from That of the Customary Commercial-Type Roots Blower. The Use of This Special Contour Results in an Increase of about 6 Per Cent in the Effective Area of the Rotors Over That of the Conventional Full-Cycloidal Rotor. The Average Clearance at All Points in the Compression Chamber Is about 0.006 In. The Timing-Gears Are Seen in Full, with the Driving Gear at the Rear and Below

three times the speed of commercial machines might very well change the accepted characteristics of the type. However, the results obtained during some tests[4] of a 5 x 5-in. commercial compressor operated against 5-lb. delivery-pressure at speeds up to 1800 r.p.m., or about three times its normal speed, lent encouragement to the project, as it was found that the volumetric efficiency did not decrease with increase in speed but, for the conditions of test, even exceeded 100 per cent due to the ramming effect of air in the inlet pipe. Also, an investigation of pressure-pulsations showed that, from this viewpoint, nothing was to be feared from high-speed operation, and that pulsations existing at the discharge side of the blower could be prevented from building-up in the discharge-line by using an air-receiver.

The Roots supercharger was designed for use on the Liberty-12 engine, and certain considerations entered to influence its proportions. As it was planned originally to mount the supercharger directly on the rear of the engine, the distance between the engine bearers limited the maximum diameter of the rotors. It was thought that the volumetric efficiency of the engine might pos-

[4] Made by Professor Trinks, of the Carnegie Institute of Technology, and consulting engineer for the P. H. & F. M. Roots Co., Connersville, Ind.

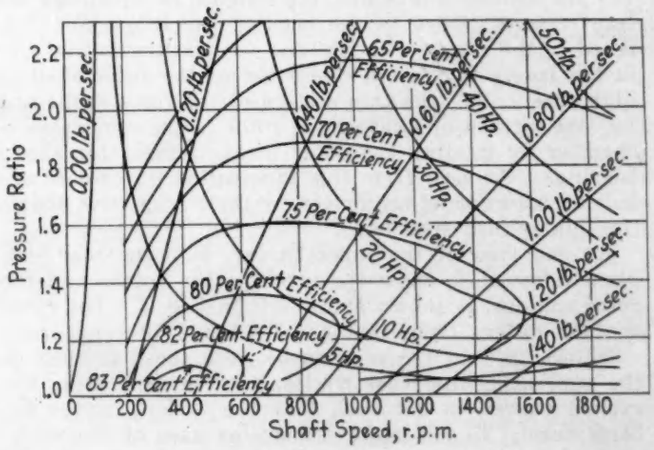

Fig. 7—Power, Efficiency and Air-Delivery Curves of Roots-Type Supercharger

The Pressure-Ratio Scale at the Left Is for a Discharge-Pressure of 14.7 Lb. per Sq. In. and an Inlet Temperature of 59 Deg. Fahr. Note the High Adiabatic-Efficiency of 83 Per Cent at a Shaft-Speed of 400 R.P.M., with Pressure-Ratio of 1.1 and Air Discharge of 0.40 Lb. per Sec. The Efficiency Is Better than 65 Per Cent, at Drive-Shaft Speeds of from 600 to 1800 R.P.M., for Pressure-Ratios up to 2.0, Which Corresponds to a Condition of Full Supercharging to 18,000-Ft. Altitude. Certain of the Variables Herein Are Segregated and Plotted on Subsequent Charts for Greater Clarity

of the engine, therefore the speed of the supercharger was fixed at 1.5 times the crankshaft-speed as for this speed-ratio there were six pulsations per revolution from the supercharger to correspond to the six induction-periods of the engine. Thus, for an average engine-speed of 1600 r.p.m., the rotor-speed would be 2400 r.p.m. The diameter and speed-ratio being determined, the length of the rotors was proportioned to handle an excess of air sufficient to maintain full supercharging to an altitude of about 15,000 ft. These considerations resulted in establishing the following proportions: diameter of rotors, 9½ in.; length of rotors, 11 in.; distance between rotor axes, 5.833 in.; rotor-speed, 1.5 crankshaft-speed.

Light aluminum-alloy castings and alloy steels are used in the construction of the supercharger, because of the exacting requirements of minimum weight compatible with ample strength. Ball-bearings are used to reduce friction and obviate the need for forced-feed lubrication. The weight of the supercharger is 88 lb., or about one-fourth the weight of a commercial blower of the same displacement.

A general idea of the external construction can be gained from Fig. 3, which shows the supercharger as mounted independently and driven through a flexible coupling. This mounting, with a flexible coupling, is used instead of the original direct mounting, with a rigid drive, to obviate possible trouble that might be encountered due to torsional vibrations in the engine crankshaft. The flexible-Thermoid coupling has a splined shaft which fits the crankshaft gear in the Liberty-12 engine. Attention is called to the deep ribbing on the side housings to provide rigidity and assure the maintenance of small rotor-clearances. The over-all width of the supercharger is 17 in., and, when it is mounted independently, the over-all length from the rear of the engine is 19 in.

Fig. 4 shows a longitudinal section through the supercharger as mounted with the Liberty-12 engine. Interesting details are (*a*) the oil-baffle at the rear of the engine; (*b*) the taper pin in the coupling, designed to shear when subjected to excessive torque and thereby permit uninterrupted engine-operation in the event of supercharger failure; (*c*) the drive and timing-gears; (*d*) the splined rotor-hubs, the tongues of which are set into recesses milled in the ends of the rotors and fastened to the rotors with screws; (*e*) the transverse ribs in the rotors to prevent distortion of the rotor shell at high speeds; (*f*) the thin section of the rotor shell; and (*g*) the method of locating the rotor in the compression-chamber by locating the outer races of the rotor shaft-bearings. As seen from this illustration, the rotors are hollow castings and are driven by their respective shafts through splined steel hubs.

An end view of the supercharger, with the rear end-plate removed to show the mesh of the rotors and the rotor contour, is shown at the left in Fig. 5. The rotor contour differs from that usually found in commercial machines, in that the relation between the diameters of the generating and base circles, used in generating the cycloid curves, is not such that the cycloid curves become normal to the major transverse axes of the rotor, as would be the case were the diameter of the generating circle one-fourth of the diameter of the base circle, which would result in an effective, or working, area equal to one-half the swept area. In forming the contour of the supercharger rotors, the diameter of the generating circle is made greater than one-fourth the diameter of the base circle, the cycloid curves being terminated at the recesses shown. The tip of the rotor is made concentric, and the mating portion at the waist of the opposite rotor is made a flat section. Due to this unconventional contour, there are, theoretically, three points of contact between the tip of one rotor and the waist of the second rotor when one is horizontal and the other vertical. Thus, with the rotor viewed in this position, the recesses form compression-spaces that would be harmful when handling a liquid, but which are permissible when handling air. By using this special rotor-contour, the effective, or working, area is increased about 6 per cent over that for the conventional full-cycloidal rotor. Further increase in this direction is limited by strength requirements at the rotor waist.

The average clearance at all points in the compression-chamber is about 0.006 in.

The gear-train and rotor-shafts are shown at the right in Fig. 5.

Laboratory Tests Show High Efficiency

A diagrammatic arrangement of the apparatus used for laboratory tests[5] of the supercharger is shown in Fig. 6. The Durley[6] thin-plate orifice method of measuring air-weight was used, and corrections to the orifice coefficients were made as found to be necessary for conditions of reversed flow[7]. Air was drawn through the orifices *d* and *e*, and the pressure-drop across the orifice was measured to obtain the air-weight. From the orifice box *f* the air passed through a regulating valve, *g*, into the depression-tank *h*, the amount of depression below atmospheric pressure in this tank being governed by the valve and varied to simulate altitude pressure-conditions for the supercharger *i*. Air was drawn from the depression-tank through a large pipe, *j*, to the intake to the supercharger, which discharged the air into an open receiver, *k*, and thence into the atmosphere. The supercharger was driven by an electric cradle-dynamometer, *l*, and power was measured by the usual torque-scales and revolution counter. Mercury manometers m, m_1, m_2, m_3 and m_4 and thermometers n and n_1 were placed as shown.

The weight of air handled and the power required by the supercharger were determined for rotor-speeds up to 2850 r.p.m. and for pressure-ratios, with atmospheric discharge-pressure, up to 2.3, thus covering the full range of operation that would be encountered in service with full supercharging maintained to 20,000 ft.

Practically the complete performance of the supercharger is shown in Fig. 7. As the information on this chart is too confusing for ready analysis, certain of the variables have been segregated and plotted on subsequent charts. However, the high value of 83 per cent for maximum over-all adiabatic efficiency, shown in this illustration, is noteworthy. Also it will be noted that, for drive-shaft speeds of from 600 to 1800 r.p.m., the efficiency is better than 65 per cent for pressure-ratios up to 2.0, corresponding to a condition of full supercharging to 18,000 ft. It will be recalled that the supercharger is geared 1.5 to 1.0.

The temperature-pressure relation for air compressed in the Roots supercharger is shown at the top of Fig. 8, the relation approximating that obtained from the equation for adiabatic compression

$$T_2/T_1 = (P_2/P_1)\ (n - 1/n) \qquad (1)$$

where

P_1 = initial pressure

[5] See National Advisory Committee for Aeronautics Report No. 230.

[6] See *Transactions of the American Society of Mechanical Engineers*, vol. 27, p. 193.

[7] See National Advisory Committee for Aeronautics Technical Note No. 40.

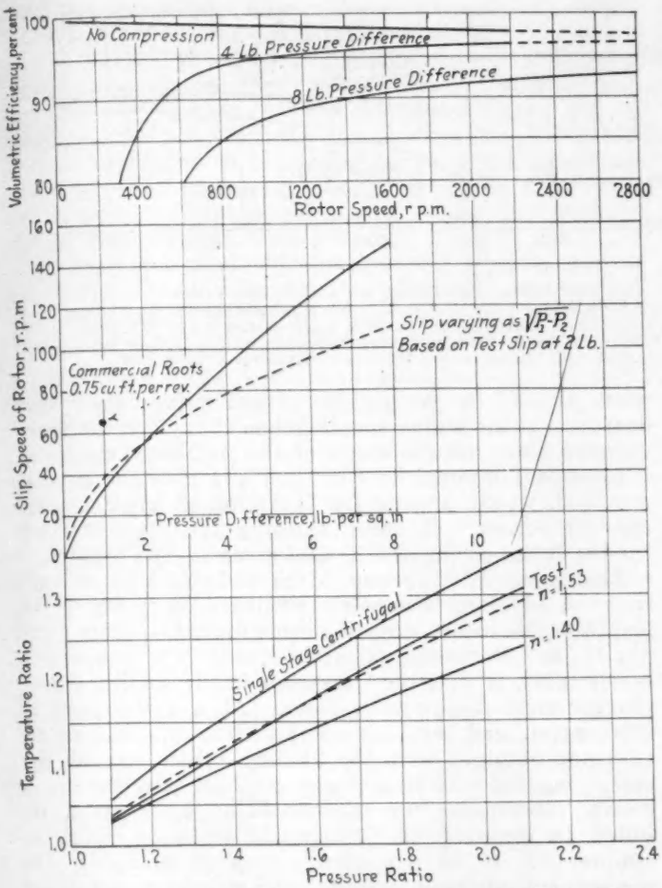

FIG. 8—RELATION OF AIR TEMPERATURE TO PRESSURE (TOP), EFFECT OF PRESSURE-DIFFERENCE ON SLIP-SPEED (CENTER) AND EFFECTS OF SPEED AND PRESSURE-DIFFERENCE ON VOLUMETRIC EFFICIENCY (BOTTOM)

The Temperature-Ratio Is for an Inlet Temperature of 59 Deg. Fahr. and a Discharge Pressure of 14.7 Lb. per Sq. In., Absolute. The Increase in Temperature of the Air Compressed in the Supercharger Is Less than That in a Centrifugal Single-Stage Compressor of Approximately the Same Capacity, as Shown by the Curve Included for Comparison. Slip-Speeds Were Measured with the Intake Blocked To Simulate Conditions That Would Obtain in Service and Are Plotted Against the Pressure-Difference between Intake and Discharge. The Dotted Lines Indicate the Way in Which the Slip-Speed Would Vary as a Function of the Square Root of a Pressure-Difference of 2 Lb. The Volumetric Efficiency Decreases Slightly with Increase in Rotor-Speed with No Compression, but at 4 and 8-Lb. Compression the Efficiency Increases with Speed. The Speed That Gives Maximum Volumetric-Efficiency Increases with Increase in Compression

P_2 = final pressure
n = a value of 1.53
T_1 = initial temperature
T_2 = final temperature

The relation for the case of adiabatic compression with n taken as 1.4, and the relation obtained in a small single-stage centrifugal compressor, are also shown. It is seen that the increase in temperature of the air compressed in the supercharger is not excessive, and is less than that obtained in a centrifugal compressor of approximately the same capacity.

Slip-speeds were measured with the supercharger intake blocked off to simulate the conditions that would obtain in service. These are shown in the middle chart of Fig. 8 plotted against the pressure-difference between intake and discharge. The slip-speed for a commercial machine, of approximately the same displacement as the supercharger, discharging against 1-lb. gage-pressure, is also shown. The dotted line indicates the way in which the slip-speed would vary as a function of the square root of the pressure-difference, and is based on the test slip for a pressure-difference of 2 lb. The difference between the test slip and the slip represented by the dotted line indicates, roughly, the deviation from the square-root law that results when slip is measured by blocking the intake instead of the discharge.

EFFECT OF COMPRESSION AND ROTOR-SPEED

Curves in the lowest group of Fig. 8 show the effect of compression and rotor-speed on the volumetric efficiency based on density of the air at the inlet. The curve for no compression shows a reduction in efficiency of about 2 or 3 per cent at a rotor-speed of 2800 r.p.m., thus indicating very small charging-loss at the higher speeds. The curves for 4 and 8-lb. compression indicate an increase in volumetric efficiency with increase in speed, as would be expected from a consideration of slip-speeds becoming a lesser proportion of the higher rotor-speeds. The conclusion can thus be drawn that, within limits not shown by these tests, the speed that gives maximum volumetric-efficiency increases with increase in compression.

In Fig. 9 are shown curves of air-weight and power, for a constant pressure-difference, plotted against rotor-speed. The curves for air-weight are, in the main, straight lines, with a slight downward trend at the lower speeds caused by slip. Transition curves are given to enable air-weight to be read in terms of volume of inlet

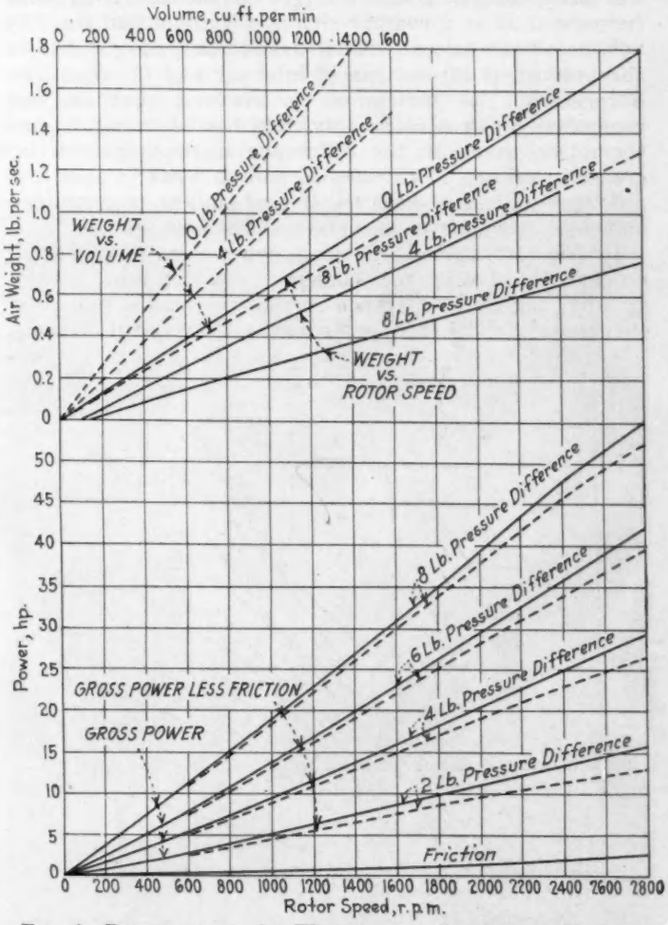

FIG. 9—RELATIONS OF AIR-WEIGHT AND COMPRESSION-POWER TO ROTOR-SPEED AT CONSTANT PRESSURE-DIFFERENCE

The Curves Are Based on an Inlet Temperature of 59 Deg. Fahr. and a Discharge Pressure of 14.7 Lb. per Sq. In. The Solid Lines in the Upper Group of Curves Show the Actual Air-Weight Delivered at Various Speeds, While the Dotted Lines Show the Air-Weight in Terms of Volume of Inlet Air Handled by the Supercharger. In the Lower Group the Solid Lines Show the Gross Power Required at Different Pressure-Differences and Rotor-Speeds, While the Dotted Lines Show the Net Power after Deduction of Friction Loss. The Last Curve at the Bottom Indicates the Friction Power with the Supercharger Operated with Free Inlet and Discharge

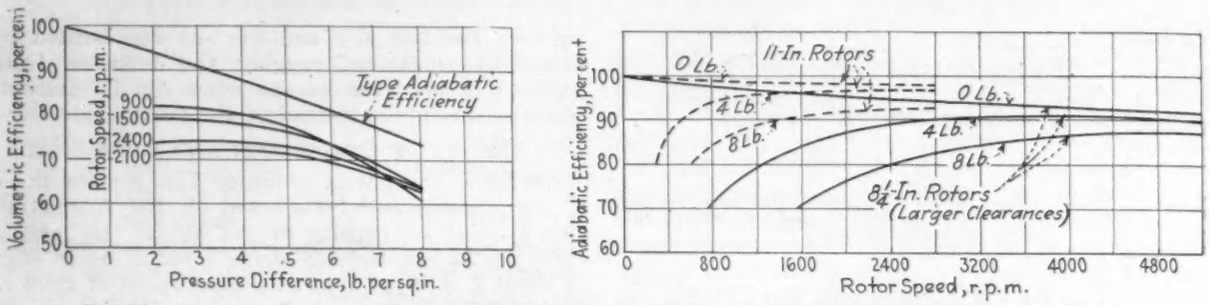

FIG. 10—ADIABATIC EFFICIENCY BASED ON GROSS POWER AND VOLUMETRIC EFFICIENCY OF TWO SIZES OF ROTOR

Rotors 11 In. in Length Gave a Volumetric Efficiency of 98 Per Cent, at a Speed of 2800 R.P.M., with No Compression, as Shown by Dotted Lines in the Curves at the Right, While 8½-In. Rotors of the Same Diameter Gave Only 95-Per Cent Efficiency, as Shown by the Solid Lines. Increasing the Speed to 5200 R.P.M. Resulted in Decreasing the Efficiency at No Compression, but with a Pressure-Difference of 8 Lb. the Efficiency Increased with Speed to the Maximum at about 4900 R.P.M.

air handled. The curves of net power, in the lower chart, are practically straight lines and show a proportional increase in net power, or gross power less friction, with increase in speed. The dotted-line curves for gross power are slightly concave upward, due to friction. The friction power, obtained by operating the supercharger with free inlet and discharge, is shown to be relatively low, even though it includes the fan power absorbed by the rotors. Information on friction power and the power required to maintain pressure with no delivery is not exact enough to enable a true comparison to be made between the net compression-power required for the volume of air actually handled and the power given by the product of the volume of inlet air and the pressure-difference. The indication is, however, that the net compression-power is greater than that obtained by the theoretical relation, the difference increasing with increase in volume of air handled and increase in pressure-difference. This indication, if true, might be explained on the basis of power loss due to turbulent air-flow.

In Fig. 10, at the left, are shown curves of over-all adiabatic-efficiency, for constant rotor-speeds, plotted against pressure-difference between intake and discharge; the discharge pressure being maintained constant at 14.7 lb. per sq. in. These curves show that operation at the higher speeds is less efficient at the lower compressions; but the slopes of the individual curves at a pressure-difference of 8 lb. indicate that the reverse condition would be true for operation at greater pressure-differences. A curve showing the type-efficiency for the Roots compressor is also given in this chart.

The curves in the group at the right of Fig. 10 indicate the effect on volumetric efficiency of reducing the length of the rotors, with the same diameter, from 11 to 8¼ in., and increasing the rotor-speed. The comparison is not exact, in that the clearances in the smaller supercharger were somewhat greater. At a rotor-speed of 2800 r.p.m. and with no compression, the volumetric efficiency obtained with the shorter rotors was 95 per cent, compared with 98 per cent obtained with the longer rotors. Increasing the rotor-speed to 5200 r.p.m. resulted in lowering the volumetric efficiency, with no compression, to 92 per cent. At a given speed, the smaller supercharger gave a lower volumetric-efficiency for the same amount of compression, as would be expected from an analysis of slip-speeds. The rotor-speed giving maximum volumetric-efficiency for a pressure-difference of 4 lb. is seen to be about 4000 r.p.m. and for a pressure-difference of 8 lb., about 4900 r.p.m. The maximum efficiencies obtained with the shorter rotors for these two pressure-differences are about 6 per cent less than those obtained with the longer rotors at a speed of 2800 r.p.m.

Fig. 11 gives the altitude performance of the supercharger and shows the power required to maintain a constant air-weight with a variable supercharger-speed, and the power required at a constant speed of the supercharger with a diminishing air-weight with increase in altitude. The air-weight has been corrected for decreased inlet-temperature at altitude.

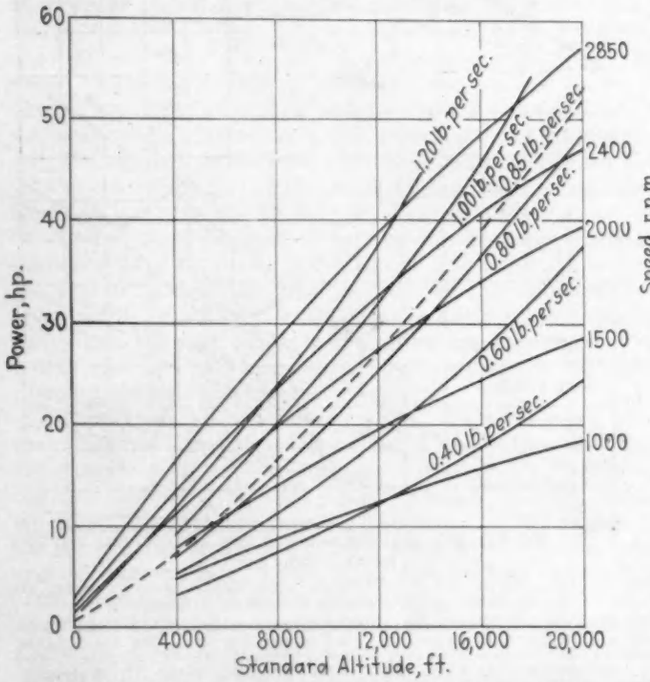

FIG. 11—ALTITUDE PERFORMANCE OF SUPERCHARGER AND POWER REQUIRED FOR CONSTANT AIR-WEIGHT AND CONSTANT SUPERCHARGER-SPEED

The Air-Weight Has Been Corrected for Decreased Inlet-Temperature at Altitude

METHODS OF CONTROL AND POWER REQUIRED

Fig. 12 shows a comparison of the power required by the three methods of supercharger control; that is, (*a*) varying the speed of the supercharger to maintain a constant air-weight to the engine, (*b*) maintaining a constant supercharger-speed and by-passing the excess air at low altitudes into the atmosphere and (*c*) throttling the intake to the supercharger to maintain a constant air-weight to the engine. The case is taken for the Liberty-12 engine operating at 1600 r.p.m., and the assumption is made that the air-weight required by the engine will be the same at all altitudes. This assumption is incorrect owing to the fact that the volumetric efficiency of the engine will increase with altitude due to the difference in pressure between the engine intake and exhaust, and for the reason that the increase in temperature of the compressed air will reduce the air-weight

that the engine can induct. The assumption is accurate enough, however, for comparative purposes. The upper curves of this illustration give the air-weight handled by the supercharger at a constant speed at altitude both for the condition of constant inlet-temperature and of varying inlet-temperature. The intersection of the air-weight handled by the supercharger with the weight required by the engine establishes what is termed the critical altitude, or highest altitude at which full pressure can be maintained at the carbureter.

In the lower group of curves it will be seen that, to supply the engine with a constant air-weight, the speed of the supercharger drive-shaft, geared 1.5 to 1.0, must be varied from 900 r.p.m. at sea-level to 1600 r.p.m. at the

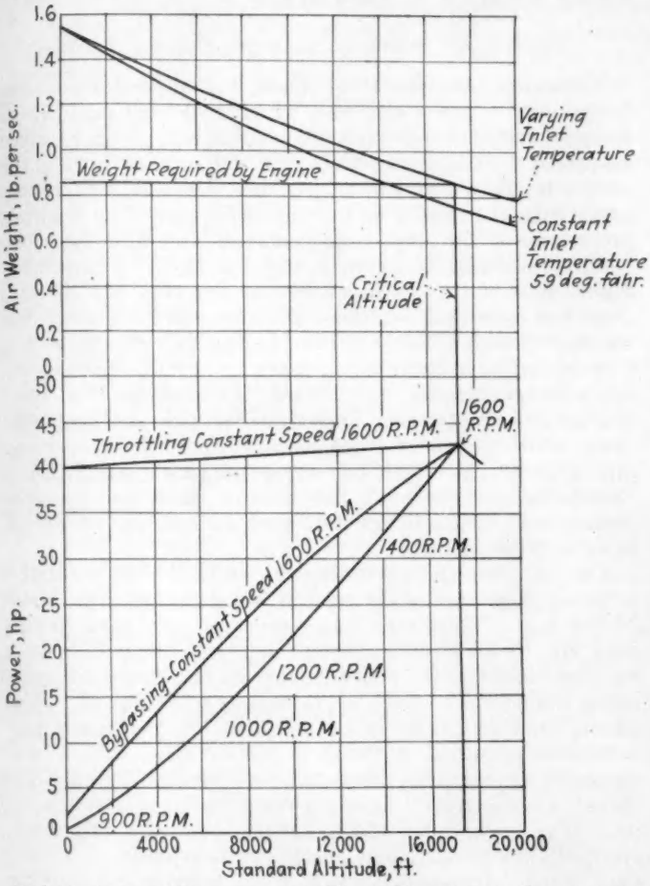

FIG. 12—POWER REQUIRED WITH THREE METHODS OF SUPERCHARGER CONTROL

The Three Methods of Control, for Which the Lower Three Curves Indicate the Power Required, Are (*a*) Varying the Speed of the Supercharger To Maintain a Constant Air-Weight to the Engine, (*b*) Bypassing Excess Air into the Atmosphere at Low Altitudes While Maintaining Constant Supercharger-Speed and (*c*) Throttling the Supercharger Intake To Maintain a Constant Air-Weight to the Engine While Maintaining Constant Supercharger-Speed. In the Analysis the Engine Is Run at a Constant Speed of 1600 R.P.M., the Supercharger Was Geared 1.5 to 1.0 and the Discharge Pressure Was 14.7 Lb. per Sq. In., Absolute. The Upper Curves Give the Air-Weight Handled by the Supercharger at Constant Speed at Altitude both for Varying Inlet-Temperatures and a Constant Inlet-Temperature of 59 Deg. Fahr. The Intersection of the Curve of Air-Weight Handled by the Supercharger with the Curve of Air-Weight Required by the Engine Establishes the Critical Altitude

critical altitude. This gives the ideal method of control but is difficult of attainment. The curve immediately above represents the power required at a constant drive-shaft-speed of 1600 r.p.m., by the method of bypassing, and shows, from the standpoint of power required, the approach to the ideal; the power required is the same at the critical altitude. The extra power required by this method is a direct function of the extra volume of air handled and the difference in supercharger friction. The

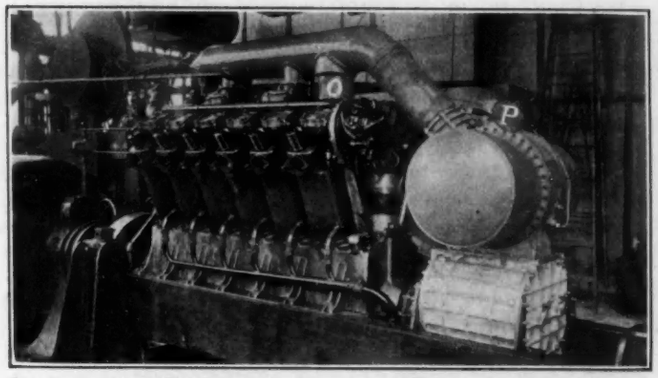

FIG. 13—ROOTS-TYPE SUPERCHARGER MOUNTED WITH LIBERTY-12 ENGINE ON TEST-STAND

Note Size and Relative Proportion of Air-Receiver and Air-Ducts Finally Adopted for Flight Test. An Automatic Inlet-Valve *O*, Assures Continued Engine-Operation If the Supercharger Fails when the Butterfly Bypass-Valve *P* Is Closed

temperature of the air supplied to the engine is the same for these two methods of control, due to the fact that the air is compressed the same amount in both cases. The third method of control, throttling the intake to the supercharger, besides being wasteful of power at the lower altitudes, results in excessive heating of the air supplied to the engine at low altitudes. The power required by this method approximates, in relative units, that required by the gear-driven centrifugal compressor; and the heating of the air in the case of the latter is even greater than would obtain in the Roots supercharger under similar conditions.

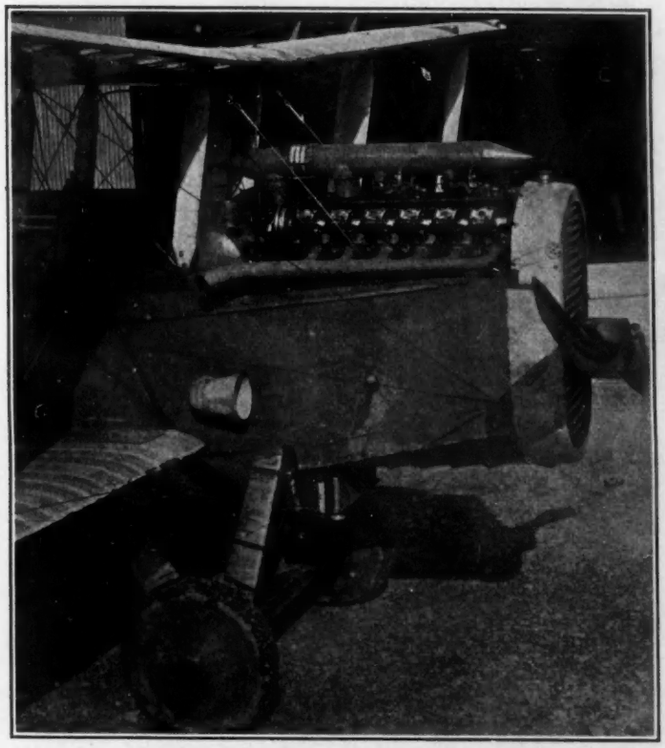

FIG. 14—DEHAVILAND-4 AIRPLANE EQUIPPED WITH ROOTS-TYPE SUPERCHARGER

Note Air-Scoop on the Side of the Fuselage That Connects with the Supercharger Intake. The Forward Projection of the Scoop Was Removed Later. A Small Booster Water-Radiator, Seen Beneath the Fuselage, Was Found Necessary When Maintaining Full Supercharging to 20,000-Ft. Altitude. Without This Booster Radiator and with Full Supercharging Maintained to 13,000 Ft. Repeated Climbs to an Altitude of 20,000 Ft. Were Made in from 20 to 21 Min.

Mounting of Supercharger with the Engine

After the series of laboratory tests to determine the characteristics of the supercharger were completed, the supercharger was mounted with a Liberty-12 engine on the dynamometer test-stand to determine suitable air-duct connections between the supercharger and the engine. In these tests, the supercharger was mounted on the engine bearers extended and was driven by the engine through a flexible coupling. The discharge side of the supercharger was connected to the engine carbureters and the inlet to the supercharger was throttled to simulate altitude conditions. Various types and sizes of air-duct between supercharger and engine were tried, both with standard Zenith and inverted Stromberg carbureters, before satisfactory engine-operation was obtained.

These preliminary tests were characterized by rough engine-operation and unequal distribution between the two carbureters, the operation being somewhat worse with the supercharger inlet throttled. The relative proportion and the size of the air-receiver and air-ducts finally adopted for flight test are shown on Fig. 13. An automatic inlet-valve was provided, as shown at *O*, to assure continued engine-operation in case the supercharger failed at a time when the bypass valve *P* was closed. The particular layout shown in this illustration was used in connection with flight testing in a DT-2 type airplane, but is similar to the installation first used in a DH-4 airplane. Later tests have shown that the size of the air connections can be reduced materially, thus effecting a considerable reduction in the weight of the total installation, which, for the layout shown, was about 150 lb., distributed as follows: supercharger, 88 lb.; coupling, 10 lb.; supercharger tank, 24 lb.; and air connection to the carbureter, 29 lb.

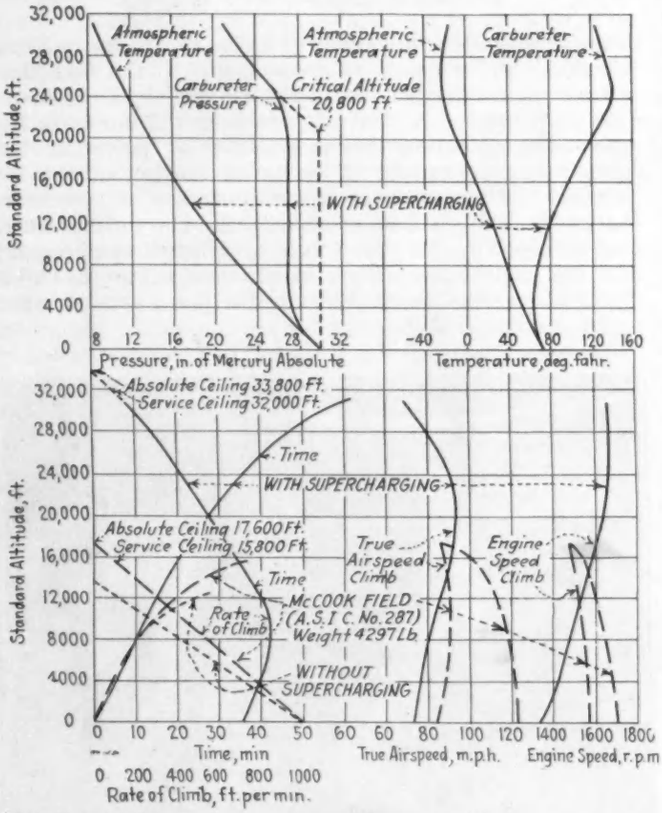

Fig. 15—Altitude Performance of DH-4 Airplane with Supercharging

Full Supercharging Was Maintained to 20,000 Ft. and the Booster Radiator Was Used. The Airplane Was Driven by a Liberty-12 Engine and Weighed 3960 Lb. A McCook Field Propeller, Serial 065,323, Was Used. Solid-Lined Curves at the Lower Left Show Time and Rate of Climb with Supercharging, the Dotted Lines without Supercharging, and the Broken Lines the Corresponding Unsupercharged Performance of a McCook Field DH-4 Observation Airplane Weighing 4297 Lb. The Absolute Ceiling, with Supercharging Maintained to 20,800 Ft., Was Increased about 92 Per Cent, the Service Ceiling 100 Per Cent, and the Time To Climb 15,000 Ft. Was Reduced from 32 to 19 Min.

Attempts to synchronize the supercharger pulsations with the engine induction-periods did not result in a measurable increase in power, as would have resulted from any increase in volumetric efficiency of the engine. This may have been due to the fact that exact sychronization could not be obtained, owing to the uneven induction-timing for the Liberty-12 engine.

Effect of Supercharger in Flight Tests

Following the laboratory tests, the supercharger was installed in a DH-4 airplane, which had been modified to accommodate the supercharger equipment. Fig. 14 gives a general view of the installation. Of interest here is the air-scoop, shown on the side of the fuselage, which connects with the intake to the supercharger. The forward projection of the scoop was removed later and the scoop made practically flush with the fuselage. Preliminary flight-trials with the supercharger drawing air directly from the space behind the engine revealed the fact that the supercharger was not obtaining a full charge of air. Consequently, it became necessary to provide leads to the supercharger intake from outside the fuselage. The small booster water-radiator, shown under the fuselage, was found to be necessary when maintaining full supercharging to 20,000 ft. With full supercharging maintained to 13,000 ft., and without the booster radiator, repeated climbs were made to an indicated altitude of 20,000 ft. in from 20 to 21 min.

Fig. 15 gives the performance obtained with the DH-4 airplane when maintaining full supercharging to about 20,000 ft. The booster water-radiator was used in this case, and its air resistance, together with the extra power required to drive the supercharger at the increased gear-ratio, reduced the climb performance to 20,000 ft. Also shown on this chart, in dotted lines, is the climb performance obtained without supercharging, which was markedly inferior to the usual performance of this airplane. Consequently, performance curves are also shown, in broken lines, for a McCook Field test of a DH-4 airplane equipped as a corps observation-airplane. The McCook Field airplane was somewhat heavier but, as the unsupercharged performance of the National Advisory Committee for Aeronautics airplane was inferior to that of the McCook Field observation-airplane, an indicative comparison can be made without favoring the supercharger. With this in mind, it will be seen that the indicated absolute ceiling, with full supercharging maintained to 20,800 ft., has been increased about 92 per cent, the service ceiling about 100 per cent, and the time to climb 16,000 ft. reduced from 32 to 19 min.

A large fixed-pitch propeller was used in the supercharged tests, which held the engine to 1320 r.p.m. on the ground compared to 1500 r.p.m. for the propeller used for the unsupercharged performance. No air-cooler was used between the supercharger and carbureters, although an average cooling of 20 deg. fahr. was obtained from the exposed air-ducts. This condition resulted in the maximum air-temperature at the carbureter of 140 deg. fahr. at an altitude slightly above the critical one.

The growing interest in air-cooled engines led to a series of investigations of the effect of supercharging on

engine and airplane performance when using the Roots supercharger mounted with the Wright J-4 air-cooled engine in a UO-1 airplane. For use with this engine, the supercharger used with the Liberty-12 engine was geared-down to give full supercharging at 18,000 ft. Fig. 16 gives an idea of the installation in the UO-1 airplane, in which the supercharger was mounted on special stringers in an inverted position owing to the location of the carbureter on the J-4 engine. An intake stack was used and carried high enough to escape the engine exhaust. A short pipe-connection was used between the supercharger and the carbureter. With the same total weight for the airplane and using the same propeller, and with full supercharging maintained to 18,000 ft., the comparative performance shown on Fig. 17 was obtained. The absolute ceiling was increased 66 per cent and the service ceiling 71 per cent. The rate of climb under supercharged conditions at low altitudes was not so good as that obtained on some other flights in which the initial rate equalled that of the unsupercharged performance. Again, no air-cooler was used, and, with the supercharger and the carbureter air-duct shielded by the engine, the carbureter temperature reached the maximum of 160 deg. fahr. Comparative cylinder-head temperatures, taken at one point in the head of each cylinder, showed an increase in the maximum temperature from 480 to 530 deg. fahr.

It was concluded from these tests with the Wright J-4 engine in the UO-1 airplane and from similar tests with a Wright (Lawrance) J-1 engine in a TS airplane, that air-cooled engines having sufficient cooling capacity for operation under all conditions as a normal engine, can be supercharged to moderate altitudes with a material gain in airplane performance and without encountering excessive cylinder-temperatures.

Conclusions Deduced from Tests

An endeavor has been made in this paper to describe some of the characteristics of the Roots-type air-compressor when adapted for use as an aircraft-engine supercharger, and to indicate briefly the results that may be expected from its use in that service.

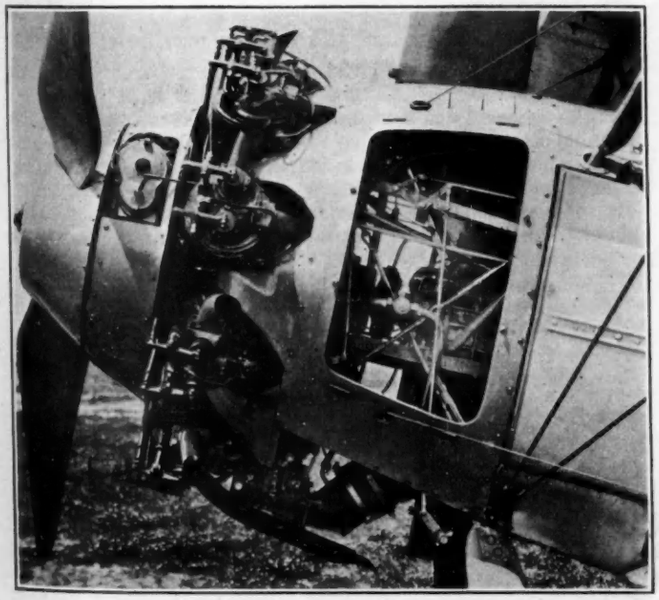

Fig. 16—Roots Supercharger Mounted with Wright J-4 Radial Air-Cooled Engine in a UO-1 Airplane
The Supercharger Was Geared-Down for Use with This Engine To Give Full Supercharging to 18,000 Ft. and Was Inverted Owing to the Location of the Carbureter

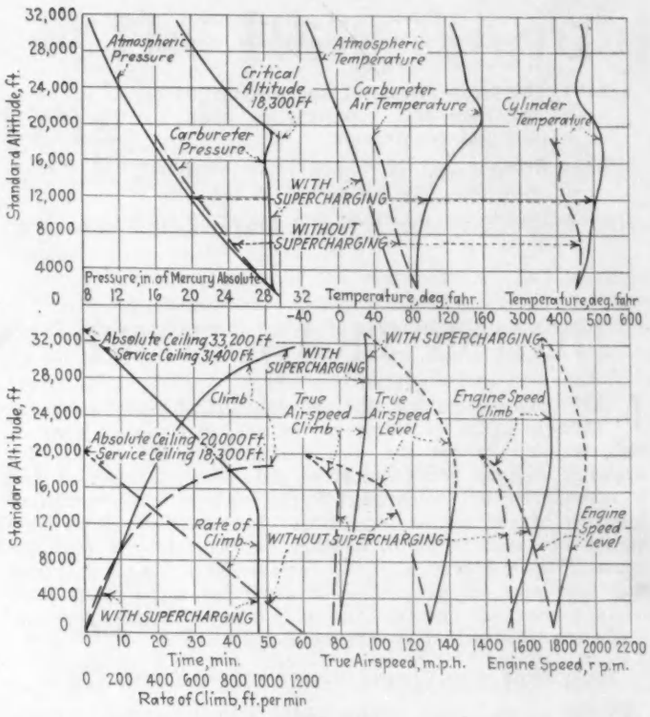

Fig. 17—Comparative Altitude Performance of Air-Cooled Airplane with and without Supercharging
In Both Cases the Total Weight Was 2060 Lb. and a Standard VE-7 Propeller Was Used. Supercharging Was Maintained to 18,000 Ft. The Absolute Ceiling with Supercharging, Shown in Solid Lines, Was 66 Per Cent Greater than Without Supercharging, as Shown by the Broken Lines, and the Service Ceiling Was Increased 71 Per Cent with Supercharging. No Air-Cooler Was Used, and the Carbureter Temperature Reached 160 Deg. Fahr. and the Maximum Temperature in the Cylinder-Heads Was Increased from 480 to 530 Deg. Fahr.

To recapitulate: The Roots compressor would seem to be particularly well adapted for use as an aircraft-engine supercharger for many service requirements for the following reasons:

(1) It can be built in sizes and operated at speeds that make it adaptable for aeronautic use

(2) It has a high over-all efficiency, even in the smaller sizes

(3) Its characteristic discharge is not necessarily detrimental to good engine-performance

(4) Due to its rugged construction, its cost of maintenance is small and its reliability and durability are favorable, which favor the production of a supercharger that will not detract from the present high standards for the normal engine

(5) Supercharging with the Roots compressor is obtained with the minimum of distress for the engine

(6) The logical method of control, which is by by-passing, results in the minimum of power required by the supercharger at the lower altitudes, thus impairing the low-altitude performance of the airplane but little

(7) Due to this method of control, the engine can be operated as a normal engine merely by leaving the bypass-valve open, in which case the power required by the supercharger is only that required to overcome friction; the use of troublesome clutches and complicated change-over valves is thus obviated

(8) Also due to this method of control, injury to the supercharger from back-firing is obviated, except for the case when the bypass-valve is closed above the critical altitude

(9) The temperature of the air supplied to the engine

is the minimum at all altitudes when supercharging, and is practically atmospheric when not supercharging

(10) The temperature of the discharged air is lower, for the same compression, than for the centrifugal compressor

(11) Because of its comparative simplicity of construction, the initial cost is low

(12) Due to its relatively low speed of operation, the need for extreme care in balancing is obviated, air-friction losses are small, and the gear problem, introduced by conditions of rapid acceleration, is not serious

In opposition to the above advantages, the Roots-type compressor has the disadvantage of bulk and weight; although the supercharger described in this paper cannot be taken as an example of the possible ultimate reduction in size and weight.

HORSE TRANSPORT AND MOTOR TRANSPORT

I AM only suggesting some of the points that have to be thought of in considering whether, in the next year or two, we can expect the disappearance of the animal for drawing wagons from our cities for economic reasons and to consider which cities might first experience the complete triumph of the engine, and why. In Paris less than 1000 horses are said to be in haulage service. Is not that because Paris is a luxury city? In New York City I gathered that last year the proportion of draft horses to commercial motor trucks was greater than in London, although, perhaps, less horses altogether as statistics show.

Sphere of the Electric and the Gasoline Cars

In the intermediate suburb could not the electric vehicle do all the work? Why not replace all horses by electric cars just a little bigger than the horse van and filled with batteries to carry them up to 20 miles per day, during which they stop and start 100 times? These ought not to cost more than the horse and harness costs to buy; these electric vehicles might be geared to go not over 15 m.p.h., and could not the chassis part be made to cost no more than does a modern horse van, one that is steel-covered with ball bearings, say £120 (approximately $580) or little more, and at a cost for use of charging plant and electric current of less than the horse costs to feed? Is this too difficult a task to set the electric-vehicle engineer?

Then, why not replace the gasoline cars on the longer journeys by electric vehicles? At a suitable point in their round they could have their depleted batteries withdrawn at a local charging-station and replaced by freshly charged batteries pushed into place by the power of an electric warehouse truck, on which they would be brought from the garage to the side of the car. Really good battery-changing arrangements would enable smaller batteries to be carried and consequently greater speeds could be attained and a quick run home at night assured. Could not one thus have an all-electric depot in a not too scattered suburb? Think of the cleanliness and silence! Men of over middle age prosper as electric-car drivers; on a gasoline car their nerves and tempers sometimes get frayed.

We have gasoline engines of many sizes and horsepowers. If we desire to substitute an engine for the power of one or two horses, can we not use one to put out just a little more energy than one or two good horses and to weigh and consume less than they do? Could we not add a small engine to a chassis that is not much different from a modern horse van with ball-bearings and steel sides, thus adding to the cost of it even less than the horse and his harness and costing less per week to operate than the horse does to feed, stable and keep? If so, where is the sphere for the horse?

We must consider the present agreement in Great Britain as to wages between masters and men whereby a motor-truck driver gets several shillings more each week than a driver of a horse drawing a similar load. Can the small motor vehicle be just so much more efficient as to enable its driver to earn these extra shillings weekly? If so, then our drivers get a little more chance of being healthier and happier men. A few shillings more per week could add to his family's share of civilization. Our duty is to make that possible, if we can.

I have spoken from the limited aspect of local distribution services, realizing that the movement of large quantities between two points may raise different problems arising from the factors of time and distance and also those of the amount that can be dealt with by one man.

Those who claim that street congestion is caused either by a slow-moving horse-vehicle or a large motor truck and trailer should take into consideration that some traffic can only bear the low cost of cheap and slow movement, whether by horse or truck, and that political action to make that traffic move faster would result in something costing somebody more money than it now costs.

If any one setting up transport equipment in a new town was flattering enough to ask my opinion as to whether I thought he wanted horses, I should say—

> Why? Have we not mechanical engines to produce any horsepower from ½ to 1000? What can the horse do for you that the engine cannot?

He might reply,

> Yes, but for some of the jobs no car, gasoline or electric, is made at present to do what I want without undue cost.

Is the demand for cars to replace the horse sufficient to enable them to be turned out "wholesale"; that is, is the demand sufficient to enable oversize and undersize motor trucks to be advertised?

If someone who had horses in transport service came and said that he thought of changing to motor trucks, and asked my advice, would not the reply be,

> You must make up your own mind. If you are being persuaded by a motor-truck salesman or your own staff or by seeing a competitor, take a holiday and think the thing out for yourself, and until you are absolutely sure, stick to your horses!

—From a paper presented by James Paterson at a meeting of the Royal Society of Arts.

Discussion of Papers at the 1926 Annual Meeting

THE discussion following the presentation of three of the papers at the 1926 Annual Meeting of the Society held at Detroit is printed herewith, the discussion following four other papers' having been printed in the July, 1926, issue of THE JOURNAL. The authors were afforded an opportunity to submit written replies to points made in the discussion of their papers and the various discussers were provided with an edited transcript of their remarks for approval before publication.

For the convenience of the members a brief abstract of each paper precedes the discussion so that members who desire either to gather some knowledge of the subjects covered without referring to the complete text as originally printed in the February, 1926, issue of THE JOURNAL can do so with the minimum effort.

CYLINDER-TEMPERATURE CONTROL BY EVAPORATION

BY A. G. HERRESHOFF[1]

ABSTRACT

ANY cooling-system is, in reality, a cylinder-temperature control-system. The best operating-temperature depends upon fixed physical-characteristics of metals, oils and gases. The advantages of a fixed temperature of 212 deg. fahr. under all operating and weather conditions are: Reduced piston-friction, better vaporization, elimination of crankcase-oil dilution and prevention of rusting, thereby increasing the life of the engine. A method of determining the cylinder-wall temperatures is described and a comparison of the temperatures for water and for steam-cooling under various operating-conditions shows that, with steam-cooling, the hot-spots are no hotter and the cooler parts of the cylinder have a more nearly uniform higher-temperature.

A description of the Rushmore steam cooling-system is given, together with the reason for the design of each part and a method of calculating its size. No change is necessary in the cylinder-block, the water-pipes are of very small size, the steam-pipe is about the same size as for water-cooling, the radiator core is capped and vented for steam distribution, a drain from the upper tank to the lower tank of the radiator permits running with the radiator full of water, the lower tank is enlarged for reserve water-supply, the air relief-valve has no function while the engine is running and the water-pump must have stainless-steel gears and shafts and be located below the reserve water-tank.

A simple and effective steam-heater for the body is supplied by small pipes and the amount of heat is constant whenever the engine is running. A hot-water-jacketed oil-pan can be used to control the temperature of the oil, thereby preventing the accumulation of diluent in winter and cooling the oil in extreme conditions in summer. The author states that engines of the future will be steam-cooled and covered with an insulating jacket to prolong greatly the cooling-off time after the engine has stopped.

THE DISCUSSION

F. J. BEDFORD:—In the Mid-Western and the South-Western States, where the water is very bad, is it necessary to use distilled water in the system?

A. G. HERRESHOFF:—No. The amount of lime deposited is in proportion to the amount of fresh water containing lime put into the system. If the system does not lose water, the new lime is not added and so will not accumulate in the system.

A MEMBER:—The first objection one hears from engineers in regard to steam-cooling is that a gear-pump or a plunger-pump is necessary. Is it possible to use a centrifugal pump? If the condenser were raised so as to necessitate very little lift for the water and the centrifugal pump were installed in a horizontal position with its shaft vertical, would not its action be sufficient to force the water through the system?

MR. HERRESHOFF:—Regarding former objections to a gear-pump, they were due to the fact that stainless steel was not available; but its use now obviates that difficulty. A centrifugal pump can be used if the speed is constant, just as a centrifugal pump is now used for feed-water supply in large powerhouses. When the speed is variable, we are working with something extremely indefinite.

CHAIRMAN H. L. HORNING[2]:—We are using a special type of centrifugal pump in connection with a steam cooling-system.

QUESTION:—Is it possible to obtain more heat from the jacket to steam-heat the body space of motor-cars or coaches effectively by the steam cooling-system than by the exhaust system?

MR. HERRESHOFF:—Yes.

QUESTION:—In what proportion?

MR. HERRESHOFF:—It depends largely upon the efficiency of the exhaust heat, which varies greatly with the amount of carbon accumulated in the heater. I have seen a 2-in. exhaust-heat pipe so plugged-up with carbon that a ¼-in. rod could not be put through it.

CHAIRMAN HORNING:—I know that motorcoaches are being well heated and the engines perfectly cooled by this system.

QUESTION:—Has Mr. Herreshoff tried the Auto-Pulse to pump the water from the condenser into the cylinder-block? It is made by Ireland & Matthews Co., Detroit, for pumping gasoline from the tank to the carbureter.

MR. HERRESHOFF:—It does not have enough capacity.

ALEX TAUB:—Mr. Herreshoff spoke of the necessity for having a positive pump. In 4 years of experimenting with steam-cooling, I have never used a positive pump. I have used a centrifugal pump only.

[1] M.S.A.E.—Manager, Rushmore Laboratory, Plainfield, N. J.

[2] M.S.A.E.—President and general manager, Waukesha Motor Co., Waukesha, Wis.

CHAIRMAN HORNING:—That is a good point; it represents the difference in the systems.

A. R. NOTTINGHAM:—Regarding water impurities, in the Mid-West we have not only hard water but alkali water, which increases the surface-tension to such an extent that the water at the disengaging surface is transformed into foam. That condition must be met.

MR. HERRESHOFF:—Under such conditions, it is desirable to use distilled water; but, as the water is retained and is not used up, that is not a serious objection. In fact, it is one of the reasons that steam-cooling is being used in the oil fields, where such conditions exist.

A MEMBER:—As I understand it, the use of a gear-pump is to secure positive water-feed. If that be true, why not put the water into the block at the bottom of the block? Obviously, it cannot flow back through the gear-pump unless the pump becomes badly worn.

MR. HERRESHOFF:—That is to provide for conditions in which the pump is not made accurately. If the engine or the car were not used for a long time, it is possible that the block would be entirely empty and some damage might be done before water filled the block, because of the small amount of water that is pumped.

A MEMBER:—The obvious way to rectify that is to provide a pump that will fill the block immediately.

MR. HERRESHOFF:—That would bring about other disadvantages.

JOHN S. ERSKINE:—Is any distinction made between pump and thermo-circulation systems? The statement was made that the normal cylinder-block construction is used. The water passages between the cylinder and the cylinder-head in the two systems under discussion are admittedly different, the thermosiphon system being free, while the pump-circulation systems frequently are restricted to give uniform distribution over the entire cylinder-block.

MR. HERRESHOFF:—The statement referred particularly to the pump-circulation type as the normal type; that is, the thermosiphon type has freer water-spaces and more volume in the water-jacket, on account of the larger-sized pipes, and would be even less likely to cause trouble.

A MEMBER:—In a water cooling-system having a radiator that weighs a predetermined number of pounds, and in a similar steam cooling-system, is it possible to use the same sized radiator?

MR. HERRESHOFF:—A smaller radiator can be used with the steam cooling-system. The efficiency of the radiator, besides depending upon the flow of air, depends upon the temperature difference between the air and the metal surface of the radiator. If the latter is maintained at a higher temperature, more heat units can be transferred by a given surface. Under normal conditions, assuming that the temperature of the top of the radiator in a water-cooled system is 170 deg. fahr. and a 20-deg. drop in temperature through the radiator, the average is 160 deg. fahr. At an air temperature of say 100 deg. fahr., this means a working temperature in the case of the water-cooled job of 60 deg. fahr. But the working temperature of the steam-cooled job is 212 deg. fahr.

A MEMBER:—In the water-cooled job the water is going down and all going in one direction. How do you separate the air and the steam?

MR. HERRESHOFF:—Install a return drain.

A MEMBER:—Were any experiments made with the steam cooling-system and the water cooling-system to compare carbon accumulations?

MR. HERRESHOFF:—We made no accurate comparisons.

A MEMBER:—We made a comparison that showed, on a job that is inclined to oil-up badly at light loads, that fouled spark-plugs are obviated with the steam cooling-system because the temperature is high enough to keep the oil dry.

CHAIRMAN HORNING:—I will state that there is much less carbon accumulation with the steam cooling-system.

R. R. MATTHEWS:—Is it not true that crankcase-oil dilution is not eliminated but merely kept at the minimum?

MR. HERRESHOFF:—It is eliminated to all practical purposes; it can be kept down to less than 4 per cent.

J. H. GEISSE[3]:—As to steam-cooling in reference to aviation work, we have been conducting tests on a steam-cooled Liberty single-cylinder engine. We are very much interested in steam-cooling from the aviation viewpoint, because we have somewhat different problems. We can use a fabric-type condenser in place of the radiator, which reduces the head-resistance considerably. It does away with the necessity of shutters, which have been a considerable trouble to us. Also, we can heat-up the engine more rapidly, and this is of value when taking-off from a catapult on a ship. We have found that the water-cooling and the steam-cooling are not very far separated, so far as the start of detonation is concerned. Some tests have shown them identical. Other tests have shown that, with a 6 to 1 ratio with water-cooling, we needed about 20 per cent benzol and, with steam-cooling, we needed 35 per cent, or about 15 per cent more. Concerning pumps, we have also operated a thermosiphon system and found that we actually had to throttle the amount of circulation in the system to get the best results. We have found that 300 per cent of the required amount is the best quantity of water to run through; above or below that quantity, the results are not so good. Regarding the pressure system, increasing the pressure usually increases the tendency to detonate. Zero pressure is the best that we have found so far.

CHAIRMAN HORNING:—One of the best ways to run a system is without a pump. We have two commercial jobs in operation in which we do not use a pump. That is a matter involving the type and the location of the radiators.

On one very interesting job, no radiator, no pump or no fan were used; that was on a concrete mixer. On account of the trouble in using a pump, a fan or a radiator, a steam cooling-system was installed which was much better than the water cooling-system. It was equipped with a large tank and only a few gallons of water were lost per day. Formerly, the tank supplied cold water in the morning, which continued for some time; but, with the steam outfit, the water in the jackets begins steaming in a few minutes and the engine is soon at a proper uniform temperature which continues all day. The operation is good, and the fuel-economy and the oil-consumption have been improved.

JOSEPH C. A. STRAUB:—What effect would steam-cooling have on a marine engine? Would special radiators be needed?

MR. HERRESHOFF:—A marine engine could be equipped to operate with steam-cooling very well. In that case the radiator or condenser could be the familiar water-cooled condenser used in steam vessels and not an air-type condenser such as is used in automobiles. It would be particularly advantageous in a motorboat, because the water temperature is very apt to be too low; also it would make possible the heating of the interior of the boat by steam.

[3] Chief engineer of the aeronautical engineering laboratory, Naval Aircraft Factory, Philadelphia.

CAUSES AND PREVENTION OF SQUEAKING BRAKES

BY F. C. STANLEY[4]

ABSTRACT

TESTS show that scratching of the brake-drum by brass wire in the brake-lining, high rivet-heads, particles of steel from the drum or grit from the road sets up vibrations in the drum and that the note given out by these vibrations is of the same tone as the ringing note produced by striking the undamped drum with a hammer. The sound can be damped or muffled by applying slight pressure to the drum at a point diametrically opposite the initial point of vibration.

From these observations the theory was formulated that brake squeaking is the undamped or unmuffled vibration of the drum caused by the plowing action of metal or grit in the lining. This theory explains the success of various methods that are used for remedying squealing brakes, which methods are enumerated and include lubrication of the lining, use of liners and shims, prevention of metal-to-metal contact by rivet heads, smoothing of the drum face, correction of eccentricity of the drum, truing the brake-band for circularity, and applying the internal and external brakes simultaneously.

Preventive measures that can be taken by the car builder are (*a*) making the drums of high-carbon steel, (*b*) assuring true circularity of the bands and (*c*) sinking the rivet heads 1/16 in. below the surface of the lining. If these measures are taken, the adjustment of the brakes to give uniform clearance at all points will result in quiet brakes.

Service-station methods of overcoming squeaking brakes are described, and in the case of badly-worn drums on used cars a very successful remedy is said to be the insertion of thin metal shims under the lining between the rivets. Use of an oily or greasy lubricant is regarded as a dangerous makeshift, as it often leads to the violent seizing of the brakes and serious damage to the car. Nine-tenths of the brake jobs that come to the service station have no free movement at the external rear anchor-support. This must be eased-up to permit the lining to make contact with the drum at the rear and to act as a damper to vibrations caused by hard particles at the forward area of high pressure. All foreign matter should be removed from between the drum and lining and if the drum is scored it should be smoothed with fine emery cloth. If the band is not truly circular and concentric with the drum, it should be peened to conform to the drum. The perfection of the rounding of the band can be tested by applying the brake and trying to insert a thin feeler-gage between the lining and drum to find a place where the lining fails to grip the drum.

THE DISCUSSION

F. C. STANLEY:—In further explanation of the tests with the Carson brake-lining testing-machine, the area of brake-lining contact is only 6 x 2¼ in., or about 13 sq. in.; all the rest of the drum is free to vibrate. Pressure is applied at the end of the brake-beam and is recorded by a dial balance. The torque is registered on a Toledo scale. The direction of rotation of the drum is toward the scale and the torque is carried through the brake-beam to the platform of the scale. The brake-shoe is shifted laterally by placing a shim on one side of the supporting rod, thus shifting the position of the shoe about 0.005 in., which is enough to remove an abrading particle in the lining from the groove it has made in the face of the drum. The squealing has been stopped, not occasionally but thousands of times, by applying pressure to the drum through a piece of leather or brake-lining, at a point 180 deg. from the brake-shoe.

In the case of a drum that has been worn down much more on the open side than on the web side, we found, in using the Bureau of Standards' machine, that the temperature at the worn side was more than 100 deg. higher than at the web side because of the great conductivity of the mass of metal in the web side of the drum. We also found that the saturant is burned out of the lining on the open side of the drum first. This condition of greater wear on the open side is very common.

When drums are worn so badly that the lining "grabs," most car owners will consent to renewal of the drums; but it is often found that, because drums are rather expensive, the service station cannot persuade the customer to renew the drums, hence recourse is often had to the makeshift of lubricating or "doping" the brakes.

WHY BRASS RIVETS ARE PREFERRED

QUESTION:—Of what metal are the lining rivets made, and what is the size of the head and of the shank?

MR. STANLEY:—We advocate brass rivets rather than aluminum or copper rivets and want them 1/16 in. below the lining surface so that the lining can wear that much before the rivets show.

QUESTION:—Why do you prefer a brass rivet?

MR. STANLEY:—Aluminum rivets are weaker at 600 deg. fahr. than brass rivets. Brass becomes granular at about 900 deg. fahr. and aluminum at about 600 deg. fahr.

QUESTION:—Have you experienced any trouble with the lining being torn away from the band?

MR. STANLEY:—During the war, when brass could not be obtained, we were forced to use aluminum rivets and had considerable trouble with the lining pulling from the band, particularly on internal shoes.

A MEMBER:—Some brake manufacturers recommend aluminum rivets.

MR. STANLEY:—There is a strong tendency to use them at present because they are cheaper.

C. N. DAWE[5]:—Many jitney operators in the city complain of squeaking brakes. This is pronounced because the mileage accumulates very fast. A driver to whom I gave a set of brake-bands having aluminum rivets returned the set to me after having covered 11,000 miles inside of 60 days and said that he had had no squeaking except at the end of the run. I think that the squeaking then was due to the fact that only half of the band was left; the other half was destroyed in that distance. It seems from this trial that aluminum rivets can reduce squeaking, but I have wondered if it is possible that the bands went to pieces on account of the aluminum rivets.

MR. STANLEY:—If the bands and rivets reach a temperature of 600 deg. fahr., that would be sufficient to allow the lining to be pulled away from the bands.

A MEMBER:—My experience has been that if the rivets are not countersunk there is less wear of the lining. I have found a definite noticeable characteristic when the rivets bear on the drum and when the lining alone bears.

[4] M.S.A.E.—Chief engineer, Raybestos Co., Bridgeport, Conn.

[5] M.S.A.E.—Chief metallurgical engineer, Studebaker Corporation of America, Detroit.

There is practically 0.010 in. less wear if the rivet heads touch the drum than if the lining alone bears on the drum; that is, when using very soft copper rivets, setting the heads flush with the lining, filing the whole lining to fit and grinding the drum smooth.

MR. STANLEY:—Copper rivets permit the embedding of grit, which scores the drums, and this is the chief disadvantage of using them. Brass rivets do not permit this embedding to such an extent, and we advise the use of brass rivets for that reason. Most of the lining on new cars is applied with cupped rivets, with the heads practically flush so that they bear on the drums. We are convinced that metal-to-metal contact is one of the chief causes of squeaking and we prefer to sacrifice a little greater resistance to wear of the lining to secure silence.

QUESTION:—Would not an aluminum rivet, which is softer than brass, upset more freely and fill the hole in the band better?

MR. STANLEY:—Most manufacturers overcome that by using a tubular brass rivet that expands and fills the hole in setting.

QUESTION:—Does not the tubular rivet become more or less corrugated or buckle instead of filling the hole completely?

MR. STANLEY:—It must be drilled so that the portion in the steel is solid and the spreading is entirely outside of the steel band or shoe. If the cup in the shank is too deep, the rivet is likely to buckle; otherwise, it will not buckle.

PERFECTLY CONCENTRIC BRAKES SOMETIMES SQUEAK

LYLE K. SNELL[6]:—We had considerable trouble with brake squeak on one make of car with which I was associated at one time. By laboratory and examination of probably 25 cars having squeaking brakes, I found that, in every case the brakes were perfectly concentric. With the contact of the lining correct all the way around, as nearly as we could determine, the brakes squeaked. If any member of the factory force said that his brakes did not squeak, an examination showed that the band was wrapping around either the upper or the lower side of the drum; the drums and bands were not concentric. That experience does not agree with Mr. Stanley's findings and I do not know the reason for the condition.

MR. STANLEY:—I can only cite a contrary experience. I had occasion to test for squeak 83 cars just as they came from a production line. The brakes of only one of that number squeaked, and that was remedied by adjustment. In every other case the bands were rounded so that the 0.005-in. feeler-gage was held at every point by a man gripping the end of the band on the form.

MR. SNELL:—In seven or eight of the cars I mentioned we tried throwing the bands out-of-round to eliminate the squeak and were successful in all cases.

J. WEBB SAFFOLD:—Were you able to stop the car with the brake after that?

MR. SNELL:—The braking was reduced; the shoes did not grip as hard as before.

A MEMBER:—Has any difference been noticed between squeaking in cold and in warm weather? The brakes on my car squeaked in summer but stopped squeaking in winter. Generally, cars squeak less during the winter.

MR. STANLEY:—I have made no such observations and have not taken the temperature factor into consideration. All the laboratory work was done at a temperature of about 70 deg. fahr. We have been experiencing squeaks intermittently on the brake-lining testing-machine during 6 months and stop them as I have indicated.

LIGHT BRAKE-LINKAGE AMPLIFIES VIBRATIONS

A. J. SCAIFE[7]:—Squeaking brakes on motorcoaches are especially annoying. We also have found that when using new linings on new drums, with 100-per cent wrap-up, there is no squeaking for possibly 2 weeks, due to the fact that the brake-lining is not so smooth as the brake-drum and does not have full bearing on the drum until the high spots have worn off; but, after a motorcoach has been run for some time, the squeaking begins. I question whether the brake-lining causes the trouble. The squeak originates in the lining, undoubtedly, but I believe the brake anchorage, the operating rods and the levers are too light. When these are made heavier the squeaking is eliminated. The vibration of the brake-lining on the drum is carried out through the brake-operating mechanism, and in all cases when the squeak is loudest the mechanism is lightest.

MR. STANLEY:—I agree with Mr. Scaife except that it is always the vibration of the drum and not the brake-lining that is transmitted when the tone of the squeak is of high pitch. We have obviated squeaking in a number of cars by putting six extra bolts through the spokes and carrying them out to within 1½ in. of the working face of the brake-drum. This changes the vibration period of the drums. We have noticed also that the brakes seldom squeak on cars that have a double attachment of the drum to the spokes, which increases the rigidity of the drum. Increasing the rigidity of the parts through which force is applied to the brakes would have a similar effect.

MR. SCAIFE:—As a test on a car that was squeaking badly, we lubricated all the connections to the brake without changing the brake adjustment and, so long as the lubricant remained in the connections, the brakes made no noise. If the joints could be kept in a bath of oil or grease there would be no squeaks.

QUESTION:—How is the fact that contact of rivets or foreign matter in the lining produces a squeak reconciled with the fact that metal-to-metal brakes do not squeak?

MR. STANLEY:—In all metal-to-metal brakes that do not squeak the drum vibration is damped by pressure at 180 deg. from the point at which metal is plowing, if any is doing so.

GRUNTING REMEDIED BY STIFFENING THE DRUM

LOUIS C. HUCK:—Occasionally, especially in heavy jobs, the brake noise is a low grunt rather than a squeak or chatter, and I have always thought this was due to a vibration of the anchorage rather than of the drum.

MR. STANLEY:—That occurs on some cars at the last moment of brake application and sometimes when backing. We have regarded it as an incipient chatter due to vibration at the anchorage, or possibly at the point at which the actuating lever is attached. It has been remedied frequently by increasing the number of bolts on the drum. That does not increase the firmness of the anchorage, yet it stops the groan.

MR. SNELL:—I have stopped that noise frequently by increasing the stiffness of the anchor pin and bracket on the housing. I think it is due to that part.

MR. STANLEY:—We have been successful in doing that in some recent cases as well as by increasing the number of bolts in the drum.

[6] M.S.A.E.—Detroit.

[7] M.S.A.E.—Field engineer, White Motor Co., Cleveland.

MR. SNELL:—Possibly the pitch of that slow grabbing is different from the pitch of the other noise that you have stopped by bolting the drums.

MR. STANLEY:—It is a very low pitch, close to what is called a chatter.

CHAIRMAN CARL BREER[8]:—Is squeaking more common with band brakes than with shoe brakes, or with the external than the internal type?

MR. STANLEY:—Within my experience, it is about the same.

SQUEAKING STOPPED BY REMOVING LINING SECTOR

A. G. HERRESHOFF[9]:—The Fifth Avenue Coach Co., New York City, had trouble with squeaky brakes for many years and finally cured it entirely by removing a portion of the lining directly opposite the point of maximum pressure. That is a standard practice today. The brakes are of the internal-band type, with 100-per cent wrap-up.

CHAIRMAN BREER:—We had a similar experience years ago. By removing a section of the lining at the anchor pin of a full-wrapping brake, we relieved the condition that caused squeaking. I think the section removed was practically opposite the maximum-pressure point.

MR. STANLEY:—A car in the market that is notorious for its squeaks is built with a 3½-in. space free of lining near the anchor and opposite the opening.

W. R. STRICKLAND:—In the case mentioned is it not true that the anchor pin is not opposite the high-pressure point and that no braking pressure comes at 180 deg. from or opposite to the high-pressure point?

MR. STANLEY:—I believe that is the case. If the ends of the band are bearing hard on the drums no dampage of the vibration by lining contact occurs at 180 deg. from that point. In this case, the lining on the upper side of the band is considerably longer than that on the lower side; that is, the anchorage is not central on the drum. It is 4 in. below center, I believe, hence it is possible that no damping-down from high pressure occurs near the ends of the band.

MR. HERRESHOFF:—Another matter became a problem on the motorcoaches in New York City in that the application of the brakes generated so much frictional electricity that passengers received a shock when they took hold of the hand rail to enter the coach. All equipment was changed to carry away this electricity.

MR. STANLEY:—The electricity probably could be conducted away by a chain that touches the ground, as is done on gasoline tank-trucks.

QUESTION:—Has softness of the lining anything to do with squeaking?

MR. STANLEY:—A soft lining permits a particle that might tend to abrade the drum to become embedded more readily so that it is out of contact with the metal; but soft lining becomes hard with pressure and use, so that it ceases to permit the embedding after a time.

HEAVY BRAKE-DRUMS RARELY SQUEAK

MR. SCAIFE:—What experience have you had with the cast-iron or semi-steel drum having a Brinell hardness of possibly 190 to 240, not only with regard to wear but as to whether it will obviate the squeal?

MR. STANLEY:—We have tried both cast-iron and wrought-iron drums. The scoring is much less on the former, particularly the grey cast-iron drums with some graphite in the metal. The tendency to squeak depends largely upon the mass of metal in the drum. A heavy drum seldom squeaks. We never have tried semi-steel drums. Some manufacturers have tried cast-steel drums with rather disastrous results, for they can be broken by a flying stone.

MR. SCAIFE:—High-carbon cast-steel drums will blister at high temperature, such as is developed in shaft brakes, and tear both the lining and the drum. We have used semi-steel; that is, a good grade of cylinder iron, running about 220 Brinell hardness, in shaft brakes and they have now run more than 70,000 miles on the motorcoach in city work and are as smooth as glass today. The brake-linings, which were previously being replaced after 4000 or 5000 miles, had run over 17,000 miles when they were removed and were only about one-quarter worn-out.

CHAIRMAN BREER:—What is the difference in wear of a lining on hard versus soft drums?

MR. STANLEY:—The lining wears much more rapidly on the soft drums. It becomes filled with steel particles from the drum. Soft drums are bad because they score rapidly and the metal is picked-up by the lining. It is a vicious cycle. No such trouble is encountered on hard high-carbon-content drums.

MR. HUCK:—If the temperature is kept low enough so that the drum does not score, will the lining wear as long as with a hard drum?

MR. STANLEY:—I think that the trouble occurs only at high temperatures, but in hilly country a surface temperature on the drums of more than 750 deg. fahr. is frequently reached.

HEAVY, RIGID, HARD DRUMS ARE QUIET

H. A. HUEBOTTER:—From the discussion, it seems that squeaking is largely a question of the vibration period of the drum. Is it not possible to design the drum so that the vibration period will be beyond the range of audibility? If the drum could be reinforced by turning-up a flange on the free edge, it might have that effect.

MR. STANLEY:—The face of the heavy drum upon which we developed our theory is about 1½ in. The casting is of the same material that is used in brake-drums; that is, 25-point carbon. It has a musical tone that is A above high C. It seems to me that it will be impossible to make drums so rigid that the tone will be beyond audibility. An increase in rigidity means an increase in the amount of metal.

A MEMBER:—We have made drums as suggested by Mr. Huebotter and obtained no favorable results whatever from reinforcing them.

A MEMBER:—A drum made of 0.6 to 0.7-carbon steel machined from a solid spun-forging will squeak if it is not hard enough. A solid billet of steel weighing 110 lb., machined on a lathe to 32 lb. and having fine circular flanges and a cooling area of about 722 sq. in., has the maximum rigidity possible for a drum of that type. The cooling flanges prevent expansion and vibration. Nevertheless, if the drum is not hard enough the brake will squeak; that is, when using an English lining.

CHAIRMAN BREER:—Can the squeak be avoided by hardening them sufficiently?

A MEMBER:—If the surface is kept smooth there will be no squeaking; but as soon as the surface begins to be plowed-up, the squeaking starts.

[8] M.S.A.E.—Executive engineer, Chrysler Corporation, Detroit.
[9] M.S.A.E.—Manager, Rushmore Laboratory, Plainfield, N. J.

A SUGGESTED REMEDY FOR CRANKCASE-OIL DILUTION

BY ROBERT E. WILSON[10] AND ROBERT E. WILKIN[11]

ABSTRACT

THE dilution of crankcase oils with the heavy ends of gasoline constitutes the outstanding present-day problem in the lubrication of automobile engines. This paper first presents the results of extensive tests designed to determine the rate and extent of dilution for various types of car under various operating-conditions. From these results it appears that, in the average car in winter service in the northern half of the Country, the viscosity of the original oil drops to about one-third of its original value in the first 150 to 180 miles of intermittent operation. Beyond this the viscosity, contrary to general opinion, remains fairly constant at an equilibrium value corresponding to about 15 per cent dilution, where, on the average, the rate at which fresh diluent enters the oil is practically balanced by the rate at which it is eliminated therefrom. Individual cars, of course, vary rather widely from this average figure, depending partly upon the design and condition of the car, but to a greater extent upon the operating conditions. Certain theoretical equations with empirical constants are shown to correspond closely to the observed curves giving the change in dilution with mileage.

With the average oil losing one-third of its viscosity in the first 150 miles of winter operation, to prescribe any ordinary type of oil which will have a really proper viscosity throughout any reasonable period of service is obviously impossible. In general, the widely used medium grades of oil, having around 325-sec. viscosity, are probably the best compromise available; but, for the first 50 miles of operation, their viscosity is considerably too high for easy starting when cold or for effective cold-lubrication in most cars. After 150 miles, the amount of dilution is, in general, so great as to reduce the viscosity to a point too low for safety, especially as road dust and grit accumulate. The use of a heavier oil accentuates the first set of difficulties and undoubtedly causes much of the scoring and wear of cylinders and rings, while the use of a much lighter oil gives an average viscosity after about 150 miles, which is far too low for safety.

As a remedy, this paper suggests the use of a fairly heavy oil, of from 500 to 575-sec. viscosity at 100 deg. fahr., blended with from 10 to 12 per cent of a distillate having a boiling range *substantially identical* with that found in the average crankcase oil at equilibrium. By this means it is possible to produce an oil with an initial viscosity around 220 sec., which, being thin enough, gives easy starting and good cold-lubrication and yet is so near the average equilibrium-dilution that, in general, it maintains a viscosity in this optimum range throughout its entire period of service. In warm weather, or in cars in which the average running-temperature is high, some of this diluent will shortly be driven-off to give a somewhat higher viscosity, which is desirable for such vehicles, while cars kept in cold garages and frequently started and stopped will have a somewhat lower equilibrium-viscosity, as is desirable for such vehicles.

These theoretical considerations have been fully confirmed by extensive comparative tests in two fleets of cars and trucks operated both summer and winter on the old and new types of oil. Changes in dilution and viscosity were followed closely, and the results for different types of car are presented graphically. If a car dilutes its oil to more than 20 or 25 per cent, the viscosity of even the new type of oil enters a range where the factor of safety is low but, in any case, the new oil is better than the old. If car builders can, by design and by education, keep dilution below 20 or 25 per cent, this oil should solve the remaining dilution problem in a very satisfactory manner. The factors and limitations that determine the optimum composition of the new type of oil are also discussed. Present specifications are, of course, not applicable to these oils.

THE DISCUSSION

CHAIRMAN H. M. CRANE[12]:—Mr. Wilson's paper presents one of the most interesting and novel suggestions that has been made at any of the fuel and lubrication sessions of the Society. I am glad that he called attention to the fact that prevention of dilution of oil by fuel is only part of the problem. The complaint that excessive wear is caused by dilution, which has prevailed for a number of years, has been due largely to dilution by water which accompanied the dilution by fuel, as the water became charged with enough sulphuric acid from the products of combustion to be a very active corroding agent.

Is Mr. Wilson offering a remedy that is within the reach of all car users? This is a composite oil, like practically every lubricating oil. Are the various necessary constituents available to meet the demands of commerce and, if so, what is likely to be the result on the commercial cost of the oil produced as compared with the cost of oils now commonly sold at filling stations?

ROBERT E. WILSON:—The manufacturing cost probably will be slightly more than that of the present medium oils because it is necessary to start with a considerably heavier base than the medium oil. This higher cost of the base is partly compensated by the fact that the diluent is cheaper per gallon than the oil itself. On the other hand, the diluent must be fractionated closely to give the best results. I should say that the price to the public would be very close to that of present motor oils. Very large quantities of all the necessary constituents are available. If the proposed oil meets all the tests as I am sure it will, it will be available throughout the Country before many years, if not months.

CHAIRMAN CRANE:—Mr. Wilson has presented to the car engineers a question that they must answer; that is, granting the suitability of this method of controlling dilution, what characteristics of this new type of oil will be the best for our purpose? He is offering a new tool with which to work and invites us to begin by writing our own specifications; at least we can start by asking for what we want. The question is too complicated for snap judgment, but I hope there are men here who will make suggestions for arriving at a conclusion as to the most desirable constituents for this non-diluting oil.

MAY HELP SOLVE TRACTOR-LUBRICATION PROBLEM

T. E. COLEMAN[13]:—I heard the first part of the paper with considerable prejudice, which most automotive en-

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[12] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

[13] M.S.A.E.—Vice-president and works manager, Madison-Kipp Corporation, Madison, Wis.

gineers would have, considering that the idea represents a deliberate dilution of the crankcase oil. However, my prejudice was overcome gradually until it, too, reached a point of equilibrium. Does Mr. Wilson believe that a point of equilibrium dilution is reached in a kerosene-burning tractor-engine? I made a test recently to determine how much diluent entered the crankcase of a typical kerosene-burning tractor-engine and, after putting small quantities of oil in to lubricate it, I took out of the engine 2 pt. of kerosene, 11 oz. of oil and 3 oz. of water. That was after a run of 1 hr. There was also half a glass of jelly-like substance in the bottom of the crankcase.

Another point is that I noticed that the runs for which charts were shown were practically all for a distance of 500 miles; no statement was made whether oil was added to the crankcase during the runs, but I suppose this was considered.

MR. WILSON:—With regard to the last point, oil was generally not added. In those instances in which it was added, it was put in immediately after the dilution was determined, and the ratio of diluent to oil in the added oil was the same as that in the crankcase so as not to upset the equilibrium; the addition merely increased the volume of diluted oil in the crankcase.

The problem of kerosene-burning tractors is somewhat more complicated than that of engines using gasoline. The diluent must be the heavy end of kerosene and we are hindered, first, by the fact that in general the boiling-point of tractor kerosene varies more than that of automobile gasoline. If, however, the tractor engineer will make provision for keeping the water out, as the automobile engineer does, I see no reason that it is not possible to find a reasonably satisfactory solution of the tractor problem, except possibly for operation in very cold weather and, under such conditions, gasoline is very generally used. I believe an equilibrium is established in kerosene-burning tractors under warm-weather conditions and that an oil of the proposed type, with somewhat more diluent of proper composition, will make a marked improvement in the lubrication of such tractors.

WATER AND DIRT MUST BE EXCLUDED

H. C. MOUGEY[14]:—The General Motors Research Laboratories have been doing a great amount of work along this line and the results agree closely with those obtained by Mr. Wilson. I want to emphasize two or three points that he mentioned. One is that water and dirt cause much trouble and nothing the oil man can do will help. They present problems that must be solved by the automotive engineer in the design of the engine.

Another point is that if we have an engine that we believe keeps out or removes water and dirt and holds dilution at a reasonable percentage, even under bad conditions in cold weather, the oil must then be of such a character that under heavy running-conditions it will not become so heavy as to cause trouble. The present Cadillac engine is designed to take care of water and dirt and to hold dilution at a reasonable percentage. Some of Mr. Wilson's oil was put in one of these engines, which was run 210 miles at high speed during the week of Jan. 19, 1926, and the oil showed a viscosity of 550 Saybolt sec. at the end of the run. This leads us to believe that perhaps a somewhat better compromise would result if this oil were made from a slightly lighter oil than the one Mr. Wilson chose. I think we agree in all other respects with regard to its merits.

The third point is that the Lubricants Committee of the Society has been working on oil specifications for a number of years and has had a great deal of discussion about specific gravity, flash, fire, and other tests. This oil, of course, cannot be specified by any of those tests. The Committee has seen this situation coming and for the last year has been working on this problem. We also found that it was impossible to accomplish anything with oil specifications unless the oil companies would cooperate. We now have a joint committee of the American Society for Testing Materials and this Society working on the problem and are trying to develop a suggestion made by Dr. H. C. Dickinson, of the Bureau of Standards, that our specifications be limited entirely to viscosity, leaving out of consideration flash, specific gravity and other characteristics that do not really matter. The Standards Department of the Society has circularized the industry on some of these suggestions and the answers received from the engineers indicate that they do not understand fully what the Committee is trying to accomplish. I hope that this work of Mr. Wilson's will clear-up the situation somewhat.

T. J. LITLE, JR.[15]:—Has the non-diluting oil been patented? If a heavy oil were added to the diluted oil in a crankcase would the mixture or the effect be somewhat the same as with the non-diluting oil?

MR. WILSON:—I will say "yes" to both questions. Of course the addition of heavy oil to diluted oil in the crankcase means that you have a dirty rather than a clean oil in the engine and also you disturb the equilibrium somewhat until the amount of heavy oil added picks up its equilibrium amount of diluent.

KEROSENE UNSUITABLE AS A DILUENT

W. G. WALL[16]:—Without question, much is to be said in favor of Mr. Wilson's idea. I am glad to see that the oil companies are getting ready to make an oil that can be used with much less trouble and much greater success. I think Mr. Wilson is a little conservative, however, regarding the amount of dilution in crankcases in cold weather. His figure for warm weather-conditions seems to be very good. My experience has been that in the winter the average dilution in most cars, especially those used for short runs about town in which starting and stopping are frequent, is about 25 per cent; and it is remarkable in how many cars, after about 2 years' use, the dilution amounts to more than 50 per cent in winter.

The real objection to dilution is that it reduces the viscosity of the oil. Engines of different design require oils of different viscosities, but I think the viscosity in most engines should be above 200 Saybolt sec. How nearly like this new oil could an oil be made by adding a certain proportion of kerosene to one or more of the well-known brands?

One of the principal troubles is dilution by water rather than by gasoline. Water causes even more trouble than dirt, I think, although dirt certainly is objectionable. The water forms an emulsion with most oils and that soon forms a sludge. Most crankcases will have considerable sludge in the bottom after the cars have run 1000 miles. Does this new oil tend to reduce the formation of an emulsion better than any regular motor-oil?

MR. WILSON:—This oil makes no substantial difference in the water problem, which is still left for the automotive engineers to solve.

[14] M.S.A.E.—Chief chemist, General Motors Corporation Research Laboratories, Detroit.

[15] M.S.A.E.—Chief engineer, Lincoln division, Ford Motor Co., Dearborn, Mich.

[16] M.S.A.E.—Consulting engineer, Indianapolis.

With regard to the first question, it is not advisable to put kerosene in a heavy-base oil, as kerosene does not serve anything like the same purpose as the heavy ends of gasoline. It is of course true that an engine could be operated at high enough temperatures to drive off the kerosene, but kerosene does not have a high enough volatility to balance that of the heavy ends of the gasoline. As I pointed out in my paper, to maintain equilibrium it is necessary to put in something that has substantially the same vapor-pressure relationships as the diluent that is found in the crankcase.

H. A. SCHWAGER[17]:—I drove a steam-cooled car for about 2 years, adding about 50 per cent of alcohol to the cooling medium in the winter and maintaining a temperature of about 170 deg. fahr., and found that practically all the difficulties of winter driving were eliminated except that of starting. Then I found that by adding 20 per cent of kerosene to a medium grade of lubricating oil I had no difficulty in starting. To determine whether the alcohol would boil-off and whether the 20-per cent dilution with kerosene would reduce the lubricating quality of the oil sufficiently to break-down the bearings, I attached a plow behind the car and cleared snow away. The machine is still in good condition and giving splendid service. This indicates that a lubricating oil can be modified with safety, as I do not believe anyone would want to give a car harder service than I have given this one.

[17] M.S.A.E.—Consulting engineer, Royal Oak, Mich.

[18] M.S.A.E.—Automotive engineer with research duties, Texas Co., New York City.

[19] See THE JOURNAL, July, 1924, p. 98.

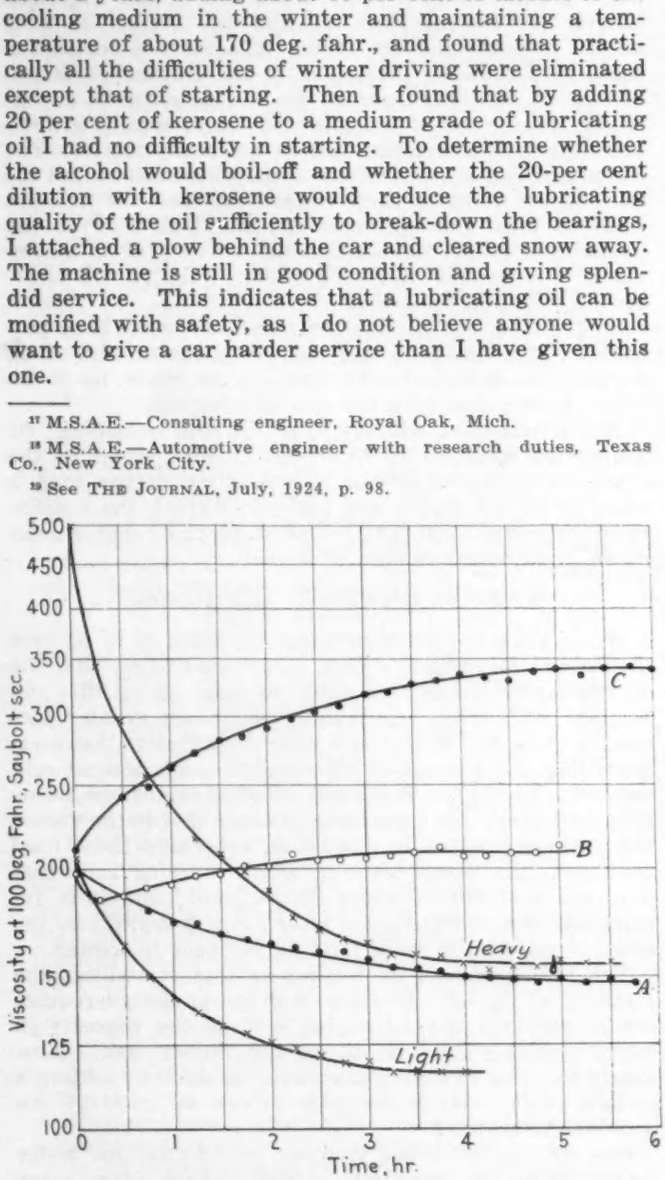

FIG. 1—RANGE OF EQUILIBRIUM VISCOSITIES OF VARIOUS LUBRICATING OILS

The Data Are Taken from Laboratory Tests Made under Conditions Identical to Those of Fig. 12 of a Previous Paper. The Viscosity of a Heavy Grade of Oil Came Down by Dilution in 4 Hr. from 500 Saybolt Sec. to an Equilibrium of 155 Saybolt Sec. and That of a Light Grade of Oil Dropped from 205 to About 115 Saybolt Sec. Of Three Different Commercial Oils That Were Prediluted with the Heavy Ends of Gasoline to an Initial Viscosity of Approximately 200 Saybolt Sec., Oil *A* Reached About the Same Equilibrium Viscosity as the Heavy Grade of Oil; Oil *B* Increased Slightly in Viscosity after 2 Hr. of Engine Operation and Oil *C* Increased Rapidly in Viscosity and Reached an Equilibrium of 340 Saybolt Sec. after 6 Hr. of Operation. Oil *B* Is Thought To Represent the Best Equilibrium Viscosity for the Average Automobile Engine

DYNAMOMETER TESTS SUBSTANTIATE ROAD TESTS

NEIL MACCOULL[18]:—My experience with non-diluting oil substantiates Mr. Wilson's in every respect. His data are primarily from road tests, which take a long time. It may be desirable in some cases to obtain results quickly to check certain ideas. I wish to call attention to some dynamometer data that show similar results in only a few hours. It is interesting to note Fig. 12 in my paper on Engine-Oil Dilution and Consumption[19], which shows that the viscosity of the lubricating oil can be maintained constant if the temperatures of the cylinder and crankcase are sufficiently high. That is one of the important advantages of steam-cooling. Temperature is a factor that always must be given particular attention in laboratory work. With a cylinder-water temperature of 190 deg. fahr. and high crankcase-temperature, an oil viscosity of 500 Saybolt sec. was maintained after 3 hr. of operation. With a crankcase-temperature maintained at 120 deg. fahr. by means of a water-jacket circulating water at a temperature of 85 deg. fahr., the viscosity of the same oil, with an initial viscosity of 500 Saybolt sec., decreased rapidly in the first 2 hr. to less than 300 Saybolt sec., and after a run of 7 hr. was still going down slowly.

Data shown in Fig. 1, presented herewith, were taken under conditions identical to those of Fig. 12 already referred to. Here, a heavy motor-oil of 500 Saybolt sec. viscosity, at 100 deg. fahr., comes down to equilibrium in barely 4 hr., after which practically no change occurs. In this case the cylinder-jacket temperature was purposely kept rather low. The water entered the cylinder-block at about 75 deg. fahr. and left it at 85 deg. fahr. By that means rapid dilution was obtained and the equilibrium point was reached in a few hours. The chart also shows a similar set of readings on a light commercial motor-oil. The viscosity of 200 Saybolt sec. comes down to an equilibrium of about 115 Saybolt sec. in 4 hr.

It is our idea, which is nearly the same as Mr. Wilson's, that the right viscosity for the average car would be about 200 Saybolt sec. in the crankcase. If it is lower the piston friction may be reduced a little, but the average engine becomes somewhat noisy with a lighter grade of oil, and that is objectionable. Therefore, the light grade of oil is shown to be entirely too low in viscosity for the average engine.

The three special oils marked *A*, *B* and *C* in Fig. 1 are made up in practically the same way as Mr. Wilson described and with the same diluent, which is simply mixed at the start with lubricating oils of different viscosity. The curves show what a great range of performance can be obtained by properly selecting the oil. The start with oil *A* is made at the same viscosity as that of the light grade of oil and it reaches about the same equilibrium viscosity as the heavy grade of oil. Oil *B* has practically the same viscosity at the start as the light grade of oil and, after a run of 2 hr., becomes slightly heavier than at the start and in 4 hr. reaches an equilibrium nearly 200 Saybolt sec. higher than that of the light grade of oil. The viscosity of oil *C* increases rapidly from 210 Saybolt sec. and reaches an equilibrium of 340 Saybolt sec. after 5 hr. of operation. All runs were made at the same temperature.

I believe that an oil such as one of these will help to remedy the conditions that exist in a large number of cars on the road in which the designers did not provide for sufficient temperature or other means of reducing dilution to the point where perfectly safe lubrication is assured.

Decrease in Oil-Consumption Noted

T. S. Sligh, Jr.[20]:—Mr. Wilson and his company are to be esteemed for their courage in fostering a proposal to engineers that crankcase-oil dilution be remedied by prediluting the oil. Everything is to be gained, I believe, by using this type of oil. The operator is better off with a non-diluting oil than with the usual oil of a lower viscosity that will permit him to start the engine easily in cold weather. On the other hand, the oil man who proposes to sell this oil has less direct gain.

Mr. Wilson seems to be very conservative in all his statements. Last winter, after having thought and talked and speculated about this idea for a year or two, we at the Bureau of Standards decided to find out what would happen with prediluted oils in an engine. We put some in the cars of some of the members of the Bureau's staff. To simplify the preparation of these oils, gasoline was used instead of the fractionated naphtha of which Mr. Wilson spoke, knowing that the lighter portion of the gasoline would pass off during the first part of the run and would be replaced later by heavy portions from the fuel. Our informal experience with this type of oil was wholly satisfactory, and in every case one of the marked changes noted was the decrease in oil-consumption. Why Mr. Wilson has not experienced this I do not know.

This is an illustration of the returns that the Society can derive from research. This idea of marketing a non-diluting oil doubtless did not come to Mr. Wilson suddenly; I think he will admit that it is largely the result of the cooperative fuel-research in which the Society has been engaged with the Bureau of Standards and others. The Society's winter tests of several years ago, in which a number of different types of gasoline were issued to operators of fleets of vehicles and the used oils were sent to the Bureau for examination, will be recalled. The results of those tests showed that if dilution were plotted against miles traveled the dilution tended toward equilibrium and also that the equilibrium dilution was greater for the heavy fuel than for the light fuel. That was the beginning of this idea of equilibrium oils, as we call them. References to equilibrium dilution, curves showing the rate of approach to equilibrium and records of cases in which prediluted oils were used and came toward the equilibrium dilution will be found in the papers and the report of that research work.

I think the proposed oil deserves the hearty support of all automotive engineers. If it is demanded it can be obtained easily and, in my experience, will be found to be much more satisfactory than the oils we have been using.

Will Help Conservation of Oil Resources

Chairman Crane:—I am glad that Mr. Sligh mentioned the oil mileage, which is one of the hardest things we have to measure today on account of dilution. In my opinion Mr. Wilson has been modest in making practically no claim for increased mileage. If mileage is based, not on the quantity of liquid in the crankcase of whatever constituency it may be, but on the time in which the liquid in the crankcase becomes of such low viscosity as to be dangerous to the engine, the figures would indicate clearly that a greatly increased mileage might be expected from non-diluting oils as compared with any but very heavy undiluted oils, which we know are too heavy for use in cold weather.

Since the war we have had a committee on fuels and later a research committee, the work of which originally was aimed at conservation of the petroleum supply. That conservation effort has been relaxed in recent years but even when it was strongest it was hard to induce the oil men to discuss the question of lubricating oils, although the oil came from the same barrel of petroleum as our fuel. The present case is one in which an oil company has permitted its representative to come before the Society and propose something that apparently leads to an economic use and conservation of oil. I am very grateful for this contribution and believe that the Society is equally appreciative.

C. A. Winslow[21]:—About 5 years ago interests with which I am associated undertook to find out how long oil in the crankcase can be used. During a period of car operation covering an indefinite number of miles we found that, if heavy oil were used, the viscosity was always equivalent to the percentage of diluent in the crankcase and results similar to those described by Mr. Wilson were obtained. We also found that the oil did not wear out but that, if a filter were interposed between the pump and the bearings to remove the contamination in the form of metal particles, carbon, sludge, and water, it was not necessary to change the oil. In other words, if we catch and drain the concentrated contamination there is no reason whatever for throwing away good crankcase oil even though diluted with fuel.

This is an appropriate time, I think, to say that the oil companies, in disclosing the fact that oil does not wear out and can be kept at an equilibrium dilution, probably will suffer a considerable reduction in the sale of oil. William F. Parish says in a pamphlet[22] on chemistry issued by the Chemical Foundation in 1925:

> In the years to come the historian will write of the American men who built so many millions of automotive engines in a few short years that by 1925 the total yearly registration reached 20,000,000. These engines represent the greatest accumulation of research and industrial knowledge ever given a mechanical appliance, and yet every one of them is lubricated with a mixture of oil, fuel, water and dirt that would not be used on the bearings of the most primitive farm machine.
>
> For the present and the immediate future, conservation of lubricants and of the petroleum fuels should be practised so as to allow these valuable reserves to carry us as far as possible. This conservation program should include the production of automotive engines that will operate more miles to a gallon of fuel and lubricant. Apparatus should be developed and adopted to correct conditions that require the frequent draining of lubricants from these engines. The draining and present waste of the mixture of lubricant and fuel taken from 20,000,000 engines is an economic blunder equivalent to the careless burning down of our forest reserves, which is being reduced only through Government supervision.

Very Little if Any Increase in Carbon Deposit

Question:—Will it be necessary to change the practice and use a higher content of carbon in the oil, and will more carbon be deposited in the engine?

Mr. Wilson:—If the new oil were made from the same crudes by the same methods of refining, it probably would show a slightly higher Conradson carbon. We know, however, that it requires a very considerable increase in Conradson carbon to make an appreciable difference in the amount of carbon in an engine, because there is far from a linear relationship between the two factors. This is especially true when, as in this case, the oil with the higher Conradson carbon is heavier, and

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[21] M.S.A.E.—Research engineer, Sheet Metal Products Co., Michigan City, Ind.
[22] See Chemistry in Industry, vol. 2, pp. 218 and 220.

hence less of it works past the rings under given operating conditions. Furthermore, by some variation in refinery methods and the selection of crudes, it is readily possible to keep the Conradson carbon the same for the two types of oil.

QUESTION:—At the end of what mileage should the proposed new oil be completely changed?

MR. WILSON:—If crankcase oil is to be changed because of dilution, it would be necessary to change it after 150 miles instead of 500 miles of operation. If there is any advantage in changing it at about 500 miles, as I believe there is, it is not because the dilution has crossed the danger point but because, for that low-viscosity oil, the accumulation of dirt and water has on the average reached such a point that it is better to start with fresh oil. The proposed oil will, of course, become contaminated with water and dirt at about the same rate, but the time of changing probably could be postponed slightly perhaps by the fact that the oil has a somewhat higher viscosity than the oil for which it was substituted, and hence could theoretically tolerate somewhat more dirt.

If cars are equipped with really efficient air-cleaners, oil-filters and water-eliminating devices, as many probably will be in the future, I know of no reason that the oil might not be used almost indefinitely. Not just one or two, but all three of these devices will be necessary, however. It will be a long time before a large proportion of the cars are so equipped, but the three devices would greatly prolong the life of the non-diluting type of oil.

INTEGRATED SERVICE AT CINCINNATI

REALIZING that industry is the dominant factor in America's economic life, and that through its development America will further the welfare of its people and give them opportunity for the greatest self development, the University of Cincinnati has worked out, under the headship of its College of Engineering, a coordination of six services to industry. It advises on raw materials, conducts industrial and basic-scientific research and has colleges of engineering and of commerce and a school of applied arts.

Cincinnati has taken a leaf from industry's own book; it has "integrated" the services that a college can render industry. The guiding hand in the development of the plan, its originator and operating executive, is Herman Schneider, dean of the College of Engineering and Commerce. It represents the fruition of the work initiated by him 20 years ago in the establishment of the cooperative system of engineering education which is now in use in 15 universities and colleges, including one medical school.

In 1920 the College of Commerce was consolidated with the College of Engineering and the cooperative system applied at once to commerce courses. Today 1200 cooperative students are enrolled. In addition, the college has instituted evening courses, in which the registration this year was 1597. Factories in which the day cooperative students work are now as far away as Flint, Mich., on the north; Elizabeth, N. J., on the east; Memphis, Tenn., on the south; and Rockford, Ill., on the west.

Dean Schneider expresses the objectives of the study and the principles of organization in the basic-science research in these words:

(1) But one set of laws can govern the actions of the 92 chemical elements that constitute matter

(2) While specialization in research work is necessary, isolation is neither necessary nor efficient

(*a*) Therefore the personnel of the laboratory will be selected on the basis of scientific specialization to obtain a well-balanced group in the fields of science—mathematics, physics, chemistry, bio-chemistry, biology, and similar subjects—as these fields are at present organized

(*b*) The problems will be attacked cooperatively. Hence the personnel must possess the additional quality of open, frank and unselfish interchange of knowledge and opinion

(3) The question of personal credit will be minimized. Our job is to give and not to get. Individual credit will be accorded freely when the work is individual, but group action and hence group credit will be a paramount essential.

—From an article by E. J. Mehren in *Engineering News-Record*.

THE ENGINEERING COLLEGE

THE engineering college is not the exclusive instrumentality of engineering education. In a satisfactory scheme it would share the field with schools giving a more intensive form of technical training and would be supplemented by means for extending professional training beyond college. The present unbalanced situation is a source of inefficiency and confusion.

The undergraduate status of the engineering college seems to be sound in principle and practice. Few institutions will give over to other colleges the entire pre-professional portion of their curriculum. A closer articulation between the programs of engineering colleges, junior colleges and arts colleges is desirable.

Engineering colleges do not claim jurisdiction over all realms of higher technical education but chiefly those relating to public works and industry. They assert their claim to a primary interest in the field of industrial operation and management. They undertake to protect the name engineering from indiscriminate use.

An engineering college cannot offer a complete professional discipline. The responsibility for shaping the course of engineering education should be shared with professional and industrial bodies, and a working collaboration for closing the gaps in the present educational scheme should exist.—W. E. Wickenden in a report to the Society for the Promotion of Engineering Education.

Oil-Rectifiers and Crankcase-Oil Dilution

At the February meeting of the Indiana Section three papers on the general subject of Oil-Rectifiers and Crankcase-Oil Dilution were presented by R. L. Skinner, president and general manager of the Skinner Automotive Device Co., Detroit; W. G. Wall, consulting engineer, Indianapolis; and J. C. Coulombe, consulting engineer, Byrne Kingston & Co. and the Kokomo Brass Works, both of Kokomo, Ind. As the discussion that followed covered the subject matter of all three papers, they are printed as a symposium.

SOURCES OF CONTAMINATION OF CRANKCASE OIL

BY R. L. SKINNER[1]

ABSTRACT

IDEAL lubrication requires that the body and the viscosity of the lubricant shall be preserved. The flash-point also must not be appreciably lowered. Contamination seriously interferes with perfect lubrication and consists of (*a*) fuel end-points, termed "dilution," (*b*) water, (*c*) acid, and (*d*) solid matter. Each of these is discussed in turn, together with the degree to which it enters into the contamination of the lubricant and its effect in producing wear on the engine.

The average dilution obtained in more than 500 samples of oil during the winter of 1924-1925 showed 39 per cent of fuel and 1 per cent of water, the maximum being 92 per cent of fuel and 3 per cent of water. The result was a reduction of all the original lubricating properties of the oil. Water causes rust, emulsifies a poor oil, is responsible for oil-pump freezing, and combines with sulphur products to form acids. Acid corrosion is evidenced by the "etching" of the crankshaft and excessive wear or stretching of the timing-chain.

The solid matter present in used oil consists of metal particles, carbon and road dust, the effects of which are dependent upon the condition of the oil. Methods of separating out the contaminating material by filtration and evaporation are described, the effective operation of the latter being governed by four factors: (*a*) temperature, (*b*) time of application, (*c*) pressure, and (*d*) the application of heat.

The principal sources of dilution in an engine are said to be unburned gasoline and condensed vapor, which accumulate on the cylinder-wall. When the engine becomes hot, practically all dilution passes the piston-rings in the form of vapor or blow-by gas. If treated in this condition, very little heat is required to separate the dilution from the oil, but if allowed to pass the piston and enter the crankcase, it becomes cooled to the temperature of the crankcase and mixes intimately with the oil, so that the time required for the removal of liquid dilution is more than four times that required for its separation when in the vapor form obtained from behind the piston-ring. The desirability of intercepting and removing dilution near its source is therefore apparent.

The results of tests made with and without the use of a rectifier are shown in tables and curves. Prevention of dilution is said to have resulted in the elimination of all excessive engine-wear, the reduction of the up-keep expense, the doubling of the life of the engine, and improved engine-performance. The recommendation is made that all new internal-combustion engines be provided with suitable equipment for the positive prevention of dilution, for it will then be possible to maintain the viscosity, pour-test and flash-point of a crankcase oil over a greatly increased period.

ENGINE lubrication is a very broad subject, regarding which many theories have been advanced and much research has been carried on to achieve perfection. The first object of good lubrication is to maintain on the moving parts of an engine a lubricating-film possessing sufficient strength to prevent the metal surfaces from coming into contact. To attain this ideal, the body and the viscosity of the lubricant must be preserved, otherwise it would be impossible to maintain the proper film between bearing surfaces under severe operating conditions. The flash-point, also, must not be lowered appreciably, if excessive wear on the cylinder-walls is to be avoided.

Oil contamination, as experienced today, is seriously interfering with perfect engine lubrication. Analysis shows that the contamination consists of (*a*) fuel end-points, termed "dilution," (*b*) water, (*c*) acid, and (*d*) solid matter. Let us consider these contaminations for a moment.

DILUTION

Tables 1, 2 and 3 show the prevalence of dilution in present-day engines. All the oil samples tested were obtained from service stations and therefore represent the average condition of the oil in the hands of car owners. The average of more than 500 samples taken during the winter of 1924-1925 showed 39 per cent of fuel and 1 per cent of water content. The maximum dilution was 92 per cent of fuel and 3 per cent of water.

The effect of this dilution on the original properties of the oil is given in Tables 4 and 5.

The lowered flash-point of the oil increases materially the loss due to evaporation from the cylinder-wall. The

TABLE 1—OIL SAMPLES FROM ONE MAKE OF SIX-CYLINDER CAR NOT EQUIPPED WITH AN OIL-RECTIFIER

Date	Mileage between Oil Changes	Total Dilution, Per Cent	Fuel, Per Cent	Water, Per Cent
March 4	500	54.0	48.0	6.0
March 4	500	19.0	18.0	1.0
March 4	500	41.0	39.0	7.0
March 17	1,000	34.0	30.0	4.0
Aug. 24	700	13.0	13.0	0.0
Aug. 24	600	17.0	17.0	0.0
Nov. 18	500	12.0	11.0	1.0
Nov. 18	500	46.5	41.5	5.0
Dec. 16	700	28.0	27.5	0.5

[1] M.S.A.E.—President and general manager, Skinner Automotive Device Co., Inc., Detroit.

TABLE 2—OIL SAMPLES FROM ONE MAKE OF EIGHT-CYLINDER CAR NOT EQUIPPED WITH AN OIL-RECTIFIER

Date	Mileage between Oil Changes	Total Dilution, Per Cent	Fuel, Per Cent	Water, Per Cent
Feb. 20	500	54	44	10
Feb. 20	500	77	69	8
Feb. 20	500	31	30	1
March 13	908	15	15	0
March 13	432	27	27	0
May 7	600	26	26	0
Nov. 19	750	42	42	0
Nov. 19	496	28	28	0

reduction in viscosity results in a thin oil-film, which causes friction and allows abrasion by fine solid particles otherwise carried in suspension.

Water and Acid

Tables 1, 2 and 3 also show the extent to which water accumulates in the crankcase. This water causes rust, emulsifies a poor oil, is responsible for oil-pump freezing.

TABLE 3—OIL SAMPLES FROM ANOTHER MAKE OF SIX-CYLINDER CAR NOT EQUIPPED WITH AN OIL-RECTIFIER

Date	Mileage between Oil Changes	Total Dilution, Per Cent
Jan. 8	500	35
March 3	500	41
March 3	500	27
June 25	550	22
Sept. 29	780	20
Nov. 12	500	20
Nov. 24	620	35
Nov. 24	500	10
Dec. 16	850	30

and combines with sulphur products to form acids. Injurious effects of acid corrosion are usually evidenced by the "etching" of the crankshaft and excessive wear or stretching of the timing-chain. Any successful method of eliminating or preventing fuel dilution through distillation automatically takes care of water, since the boiling-point of water is lower than that of the heavier fractions of fuel. As the formation of sulphurous acid is dependent upon the presence of water, removal of the latter also ensures freedom from this contamination.

The solid matter present in used oil has been shown by analysis to consist of metal particles, carbon and road dust. The proportions in which they are found depend entirely upon the condition of both the oil and the engine. Their effect is dependent solely upon the condition of the oil. Dilution breaks down the oil-film, allowing abrasive action by solid matter, thus accelerating wear. An oil of correct viscosity, on the other hand, not only eliminates abrasive action, but minimizes the accumulation of this form of contamination. Some idea of the average size of the solid particles accumulating in the

TABLE 4—A TYPICAL CASE OF USED CRANKCASE OIL[2]

Test	New Oil	Used Oil
Specific Gravity	0.925	0.895
Flash-Point, deg. fahr.	360	145
Fire Test, deg. fahr.	400	...
Pour Test, deg. fahr.	5	Below Zero
Viscosity		
At 104 Deg. Fahr., sec.	260	66
At 140 Deg. Fahr., sec.	106	...
At 210 Deg. Fahr., sec.	48	...
Fuel, per cent	...	21.90
Foreign Material, per cent	...	0.05
Water, per cent	...	Trace

[2] Sample was taken from a physician's car operated in cold weather for only 200 miles.

crankcase oil can be gained from the three views of Fig. 1. These photographs show the size of solid particles in the crankcase oil of three engines. The space between the black lines indicates 0.0002 in. The magnification of the particles is approximately 80 diameters. Most of them are less than 0.0001 in. in thickness. It will be noted that these particles are so small as to be rendered harmless in a proper oil-film.

Although filtration of the lubricant will remove most of the contamination due to solid matter, dilution will still cause wear through solid friction. This is evidenced by excessive wear during the winter season when

TABLE 5—ANOTHER EXAMPLE OF USED CRANKCASE OIL[3]

Test	New Oil	Used Oil
Specific Gravity	0.930	0.902
Flash-Point, deg. fahr.	360	145
Fire Test, deg. fahr.	400	155
Pour Test, deg. fahr.	30	Below Zero
Viscosity		
At 104 Deg. Fahr., sec.	495	96
At 140 Deg. Fahr., sec.	176	...
At 210 Deg. Fahr., sec.	58	...
Fuel, per cent	...	24
Foreign Material, per cent	...	0.53
Water, per cent	...	Trace

[3] Sample was taken from a salesman's car after 221 miles of service in winter weather.

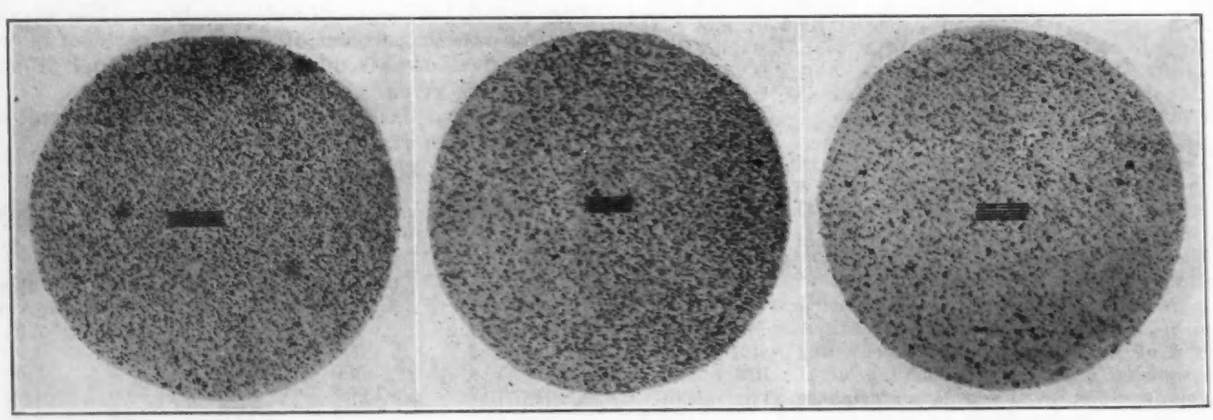

FIG. 1—PHOTOGRAPHS SHOWING THE SIZE OF PARTICLES OF DUST, GRIT AND CARBON FOUND IN THE CRANKCASE OIL OF THREE ENGINES

From Left to Right, the Engines Are a 40-Hp. Tractor, a 60-Hp. Tractor and an Automobile. The Space between the Black Lines Indicates 0.0002 In. in Each Case. The Magnification of the Particles Is Approximately 80 Diameters

TABLE 6—ANALYSIS OF MIXTURE DRAWN FROM THE PISTONS OF A SIX-CYLINDER ENGINE[4]

Material	Analysis, Per Cent	Analysis of Sample From Crankcase, Per Cent
Oil	73	93
Fuel	25	7
Water	2	None

[4] Sample obtained during first mile after cold start. Air temperature, 38 deg. fahr. Sample cooled before collecting. Normal use of choke on starting. Driving in city traffic. Quantity of liquid collected in 1 mile, 200 cc.

there is the minimum amount of dust but the maximum of dilution. Effective prevention of dilution, however, will eliminate nearly all other contaminations and will render virtually harmless such as may be present. Let us consider broadly, therefore, the difficulties to be encountered in removing dilution.

Factors Governing Effective Evaporation

The small difference in specific gravity between the end-points of oil and fuel renders mechanical separation practically out of the question. The variance in the boiling-points of the liquids, however, makes practical the use of evaporation as a purifying medium. Effective evaporation is governed by four major factors: (*a*) temperature, (*b*) time of application, (*c*) pressure, and (*d*) heat application. High temperatures aid distillation and reduce the time required. Low pressure, or vacuum, aids distillation by reducing the boiling-point of the liquids to be removed. To obtain good heat-application, the effective surface of evaporation should be the maximum. Moreover, the retort must be designed to ensure that all the liquid treated will come into close contact with the heating surface. Aeration of the mixture is especially desirable because it greatly aids in producing these results. After evaporation has been produced, mechanical separation of vapors from the oil must be effected immediately before any condensation can occur. For the greatest efficiency, therefore, it is necessary that the heater and the separating compartment be integral.

The importance of a correct heat condition cannot be overestimated. Although heat is essential for the removal of dilution, excessive heat will cause rapid oxidation of the oil, resulting in the formation of carbon in the retort and undesirable changes in the physical properties of the oil. The use of sub-atmospheric pressure, aeration and an integral heater and separating chamber makes possible the successful removal of the diluent at safe temperatures.

Principal Sources of Dilution

The principal sources of dilution in an engine are the unburned gasoline and condensed vapor that accumulate on the cylinder-wall. As this contamination works down past the piston-rings, its harmful effect begins immediately. The oil-film between the piston skirt and the cylinder-wall is broken down, allowing solid friction and, consequently, excessive wear.

By means of suction applied through openings in the cylinder-walls, the mixture of liquids and gases drawn from behind the lower piston-ring has been studied. An average analysis of the mixture obtained during the warming-up period of a six-cylinder car is given in Table 6. The condition of the dilution when removed at this point is especially interesting. It consists of very finely divided particles in suspension, somewhat resembling a fog. Of course, when the engine becomes hot, practically all dilution passes the rings in the form of vapor or blow-by gas, so that very little heat is required to separate it from the oil, if it is treated in this gaseous condition.

If dilution is allowed to pass the piston and enter the crankcase, it becomes cooled to the temperature of the crankcase and mixes intimately with the oil. Considerably more heat is required for the removal of dilution in the liquid form. Table 7 shows the comparative times required to remove the two forms of dilution at identical operating temperatures. It will be noted that the time required for the removal of liquid dilution is more than four times that required for the separation of the vapor form obtained from behind the piston-ring, which would require an excessive volume in the separating-chamber. A reduction in this volume would shorten the time-interval for treatment, but, in turn, would necessitate higher operating-temperatures, if the dilution were to be completely removed. These temperatures have been found, however, to exceed the limit imposed by carbonization of the oil.

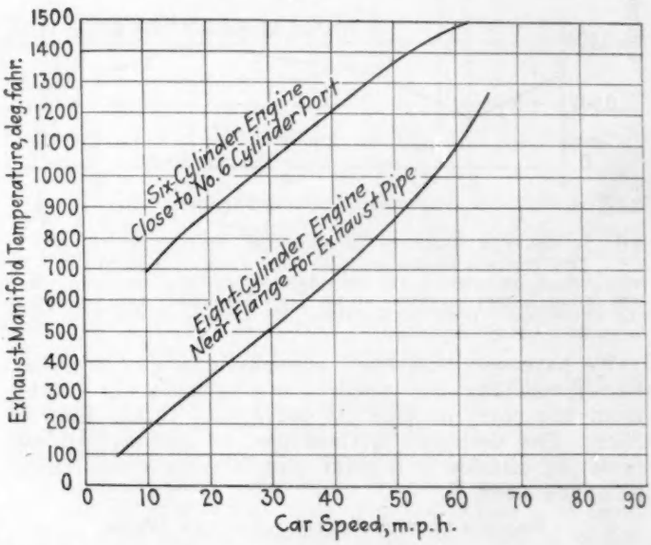

Fig. 2—Typical Heat Conditions Observed in Some Exhaust Manifolds

The Amount of Heat in the Exhaust Naturally Increases with the Speed, Whereas the Heat Required for the Removal of Dilution Decreases with the Speed

TABLE 7—HEAT REQUIRED TO SEPARATE THE DILUTION FROM THE OIL

Condition of Fuel	When Drawn from Pistons Fog	When Drawn from Crankcase Liquid
Per Cent of Fuel	25	25
Rate of Flow per Hr., qt.	6	6
Temperature Entering Retort, deg. fahr.	175	160
Temperature in Retort, deg. fahr.	300	300
Pressure in Retort	12 In. Vacuum	Atmospheric
Time of Treatment for Complete Separation, min. sec.	3—6	12—42

Logical Place for Attaching Retort

Since the exhaust-manifold affords an abundant supply of heat, otherwise wasted, it is logical that the retort be attached at this point. In a study of conditions in the exhaust systems of various engines, apparatus, consisting of thermocouples and pyrometers, was installed on several cars, allowing observation of the actual conditions encountered on the road through the range of driving speeds. Fig. 2 shows typical heat conditions

observed in some exhaust-manifolds. The amount of heat in the exhaust naturally increases with the speed, whereas the heat required for the removal of dilution decreases with the speed. Hence, it is obvious that some means of controlling the application of heat is necessary, if carbonization and evaporation of oil are to be prevented. This, of course, is a problem of design. It requires considerable study, however, before the proper application can be determined.

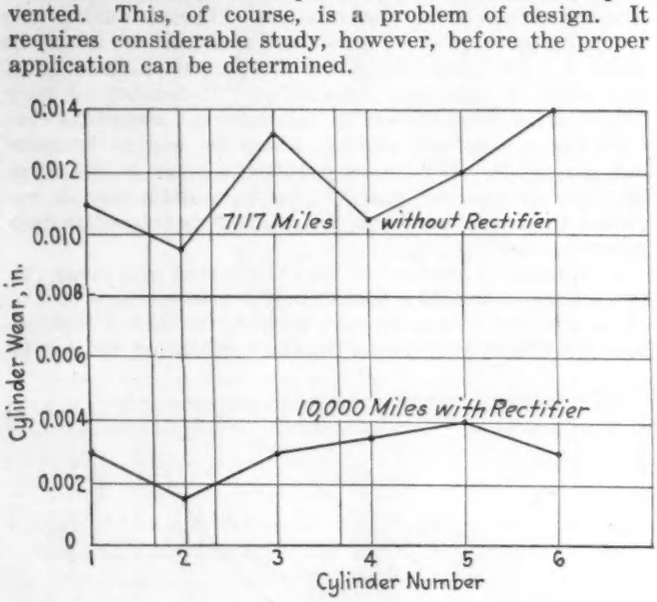

FIG. 3—RELATIVE AMOUNTS OF CYLINDER WEAR ENCOUNTERED IN TWO ENGINES OPERATED WITH AND WITHOUT A RECTIFIER

When Operated without the Rectifier, the Oil Was Changed Every 500 Miles, Removing Much of the Dirt That Had Accumulated in the Crankcase. With the Rectifier, No Change of Oil Was Made

We have seen that many advantages are to be gained by approaching the problem of crankcase-oil dilution from the point of view of prevention rather than of cure. The desirability, therefore, of intercepting and removing dilution at a point near its source can readily be appreciated.

PROCEDURE FOR TESTING ENGINE WEAR

A builder of six-cylinder cars adopted a standard procedure for testing engine wear, in which the engines were run for 10,000 miles on a dynamometer at 2000 r.p.m., the load being that required to maintain the equivalent car-speed. A spoonful of road dust was sifted into the carbureter air-intake each hour to accelerate the wear. Comparative tests were made with and without the rectifier. Without the rectifier, the oil was changed every 500 miles, thus removing much of the dirt that accumulated in the crankcase. With the rectifier, no change of oil was made. Fig. 3 shows the relative cylinder wear encountered in the two engines.

The test on the standard engine was discontinued at 7000 miles due to bearing trouble and excessive knocking. The engine with the rectifier was the only 1 out of 14 similar wear-test engines to complete this grueling test without bearing trouble.

A road test also shows the effect of preventing dilution under actual driving conditions. A stock Ford engine was equipped with the rectifier last summer and completed a transcontinental run of 10,200 miles without a change of oil. No air-cleaner or oil-filter was installed and, moreover, 20 per cent of the fuel used was kerosene. Table 8 shows the analysis of the oil at the end of the run, as reported by an oil company's laboratory. This company also reported that "dust was conspicuous by its absence."

TABLE 8—ANALYSIS OF FORD OIL, AFTER 10,221 MILES OF USE IN CROSSING THE COUNTRY

Test	Used Oil	New Oil
Specific Gravity	0.916	0.915
Flash-Point, deg. fahr.	290.00	360.00
Pour Test, deg. fahr.	.....	.....
Viscosity		
At 104 Deg. Fahr., sec.	224.00	197.00
At 210 Deg. Fahr., sec.	45.50	45 to 46
Fuel Dilution, per cent	5.00	.....
Insolubles, per cent	0.15	.....
Ash, per cent	0.18	.....

Table 9 shows the results of a road test conducted by a prominent manufacturer to determine the merits of the rectifier. These tests consisted of 25,000 miles of day and night running over routes selected to give every conceivable kind of driving condition. The crankcase oil was not changed during the entire test, yet the maximum wear on the cylinder-block was found to be less than 0.001 in.

DILUTION OF CRANKCASE OIL OF A MOTORCOACH

An analysis of engine oil drained from a motorcoach that had been run 10,000 miles without a change of oil showed fuel dilution, 3.00 per cent; water, 0.00 per cent; insolubles, 0.17 per cent. The insolubles were almost

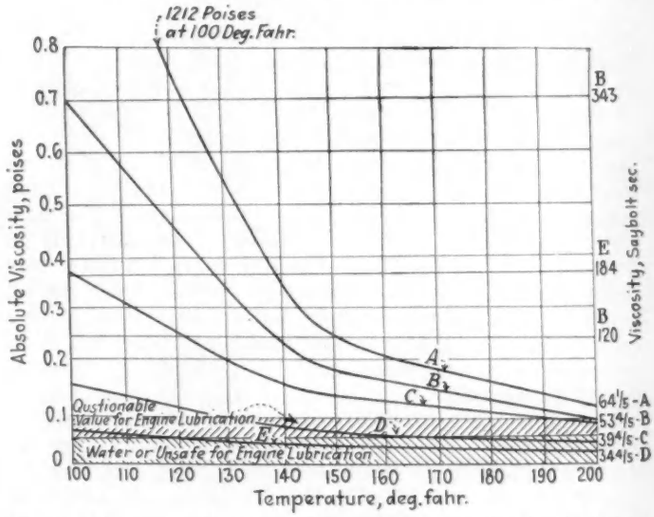

FIG. 4—VISCOSITY CURVES SHOWING EFFECTS OF OIL DILUTION THROUGHOUT THE NORMAL OPERATING-TEMPERATURES OF THE OIL IN AN ENGINE

The Area at the Bottom of the Chart Represents Oils Whose Value for Engine Lubrication Is Unsafe. Curve *A* Is the Viscosity Curve for a Medium Oil. Curves *B* and *C* Represent Respectively the Average Winter Condition of the Same Oil in Engines Equipped with and without a Rectifier. Curve *D* Is Typical of Conditions in Too Many Cars during the Winter Season

TABLE 9—SUMMARY OF 25,000-MILE TESTS OF SIX AND EIGHT-CYLINDER CARS WITHOUT OIL-CHANGE

	Six-Cylinder	Eight-Cylinder
Distance Traveled, miles	25,000	25,000
Time on Road, hr.	836.00	806.00
Average Speed, m.p.h.	29.90	31.00
Gasoline Consumption, gal.	1,692.00	2,279.50
Gasoline, miles per gal.	14.80	10.95
Oil Consumption, gal.	14.80	15.50
Oil, miles per gal.	1,688.00	1,610.00
Crankcase-Oil Dilution at End of Run, per cent	3.50	2.00
Major Repairs during Run	None	None
Crankcase-Oil Changes during Run	None	None
Man-Hours Required To Put Cars in Perfect Operating Condition at End of 25,000-Mile Run	7.00	9.00

entirely carbonaceous matter caused by the breaking down of lubricating-oil.

The harmful effect of corrosion has been previously mentioned. This is especially noticeable on timing-chains. More than 50,000 cars are operating with an efficient system for preventing dilution, on which not a single chain has been replaced. Some of these cars have been driven more than 45,000 miles. A large chain-manufacturer examined one of these chains after 30,000 miles and reported "no measurable wear."

Fig. 4 explains how these results are obtained. The viscosity curves shown are carried through the normal operating-temperatures of the oil in an engine. The area in the bottom of the chart represents oils whose value for engine lubrication is unsafe. Curve *A* is the viscosity curve for a medium oil. Curve *B* represents the average winter condition of the same oil in engines equipped with our system. Curve *C* represents the average winter condition of the same oil in engines without our system. Curve *D* is typical of conditions in too many cars during the winter season.

Methods are at hand that will take care of the present lubrication problem and will allow oil to be run in the crankcase for several thousand miles without danger of dilution. This has resulted in the elmination of excessive engine-wear, reduction of the up-keep expense, doubling of the life of the engine, and improved engine performance. Manufacturers are realizing the necessity for such protection and are equipping their cars with suitable appliances to maintain the proper viscosity of the oil, thereby preventing premature wear.

Conclusion

In conclusion, I would make this recommendation: Build all new internal-combustion engines with suitable equipment for the positive prevention of dilution. It will then be possible to maintain the viscosity, pour-test and flash-point of a crankcase oil over a greatly increased period. Not only will this result in lengthening engine life but it will also assist in conserving an irreplaceable natural resource.

THE OIL-RECTIFIER

BY W. G. WALL[5]

ABSTRACT

LUBRICATING-OIL, despite the abuse it receives, is expected to perform its function properly. Road dust, gasoline and water are allowed to mix with it, and it is subjected to a high temperature and mixed with carbon, so that the original oil soon becomes hardly recognizable. Some remedies that have been proposed provide for the removal of either the dirt or the dilution, but both should be kept out. Water not only dilutes the oil, but forms sulphurous acid, rusting the parts and, in winter, probably freezing at the oil-pump. When mixed with oil, it forms an emulsion and when this emulsion is mixed with road dust or carbon particles, sludge is gradually formed. Sludge, when agitated and sucked through the oil-pump, tends to clog the oil-holes and to wear the bearings. Oil, when exposed to a high temperature on the cylinder-walls, becomes oxidized and black in color. Sulphur in the fuel probably forms sulphur dioxide and, by mixing with water in the crankcase, becomes sulphurous acid.

A rectifier is described that has been designed to take out all the water and to keep the diluent between 4 and 5 per cent and the viscosity above 250 sec. at 100 deg. fahr., the oil being forced through by pressure of the oil-pump at the rate of about 3 gal. per hr., that of an ordinary crankcase being filtered and going through the distilling apparatus about once every hour. Emphasis is placed on the fact that, in accordance with Dalton's law, gasoline can be removed from oil without heating it to a high temperature; that practically all the gasoline diluent can be removed at a somewhat lower temperature than would be supposed to be possible. As a temperature of at least 650 deg. fahr. is required to crack lubricating-oil into gasoline, the possibility of such cracking rarely exists, for the oil seldom if ever reaches so high a temperature.

A good commercial rectifier should, it is stated, strain the dirt out of the lubricating-oil, distil off the gasoline and water diluent, maintain the viscosity of the oil, eliminate the necessity for draining the crankcase so often, increase the oil mileage materially, permit the use of lighter grades of oil the year round, keep the pistons sealed, increase the compression and power, and help to prevent the fouling of the spark-plugs, and, by eliminating the water, prevent the freezing of the oil-pump in cold weather, rusting, and the formation of sulphurous acid and sludge.

A CLOSE study of the properties of lubricating oils and the treatment they receive in the average motor-car rather leads us to the conclusion that a gasoline automobile-engine is no place for a self-respecting oil. We put fine new oil into the engine, do about all the things to it that we should not do and still expect it to lubricate all the parts properly.

We begin by letting road dust into the cylinders of the engine through the carbureter, and it gradually works its way past the pistons into the crankcase. Some also gets in through the breather-pipes, producing a very good grinding-compound. We allow gasoline to mix with the oil, also water, some of which comes from combustion and, in cold weather, from condensation within the crankcase; and all this time we are subjecting part of the oil to a high temperature and mixing carbon with it, so that after a short time the original oil is hard to recognize.

Some of us have been doing what we could to remedy this condition and, although we have gone at it in different ways, we all have had the same end in view. Some have worked on the theory that, if the dirt is kept out, or if the dirt that is in the oil is strained out, the thin oil, due to dilution, will not be harmful. Others have worked on the theory that, if the gasoline and water are kept out and the viscosity of the oil is kept up fairly well, the dirt will not do much harm on account of the thick oil-film between the moving parts.

Effect of Dirt and Dilution

I believe that it is necessary to work along both these lines and either keep out or get rid of both the dirt and the dilution. Few engineers appreciate the enormous amount of dirt that gets into the engine or the amount of dilution that gets by the pistons, or the great amount of water in the crankcase. This water not only dilutes the oil but also forms sulphurous acid, rusting the parts and in winter probably freezing at the oil-pump, besides being instrumental in forming sludge.

Ordinarily, oil and water will not mix but, with the

[5] M.S.A.E.—Consulting engineer, Indianapolis.

agitation due to the churning of the crankshaft and the movement of the pistons, they form an emulsion. When an emulsion is mixed with road dust or carbon particles, it gradually forms what is called sludge. If this stayed in the bottom of the crankcase and were not agitated in any way or pumped through the oil lines, it would not do much damage but, as it is sucked into the oil-pump and from the pump probably into the crankshaft, it has a tendency to clog the oil-holes and rapidly wear the bearings. Any strainer that takes out the dirt helps to alleviate these faults; but, to eliminate the sludge entirely, it is necessary to get rid of all the water in the crankcase.

Oils used in an engine soon become oxidized and black in color, due to the fact that they are exposed to very high temperatures on the cylinder-walls. These temperatures often reach 2500 deg. fahr. The oil also becomes oxidized by being heated to a high temperature, due to contact with the under side of the piston-heads.

Sulphur

Sulphur in the fuel, especially fuel containing benzol. often causes trouble. The sulphur probably forms dioxide and, by mixing with water in the crankcase, becomes sulphurous acid.

Emulsification and saponification are often confused. The former is a mechanical mixture of water and oil; the latter is a chemical combination of oil and water in the presence of an alkali.

I believe that a small amount of dilution in the crankcase, when no water is present, does no harm; in fact, in cold weather as much as 4 or 5 per cent of diluent is possibly beneficial, but more than 10 per cent is certainly detrimental. The purpose in using this rectifier has been to take out all the water and to keep the diluent between 4 and 5 per cent and the viscosity above 250 sec. at 100 deg. fahr.

In cold weather, very few engines, when operated without a rectifier, show less than 25-per cent dilution; they also show considerable water. A large number show from 40 to 50 per cent dilution and a viscosity as low as 80 sec. after a few hundred miles' run.

In fact, I have just received an analysis of some oil taken from a well-known car that had been run 480 miles. It showed 28 per cent of diluent, which is fairly low during March, and 4¾ per cent of water, but the viscosity was down to 54 sec.

Method of Operation of Rectifier

In the device I shall describe, the oil is forced to it by pressure of the oil-pump at the rate of about 3 gal. per hr., somewhat slower when the engine is running at low speed and faster at high speed. That is, the oil in an average-size crankcase is filtered and goes through the distilling apparatus about once every hour. The temperature of the oil in the distillation-chamber will vary somewhat with the heat of the exhaust and with the speed of the engine and ranges from 180 to slightly less than 275 deg. fahr.

The question is often asked: How can you get all the gasoline out of the oil without heating it to a high temperature, when the end-point of the gasoline used at present is 450 deg. fahr., or even higher? This is best answered by referring to one of Dalton's laws, which is, that when exposed to normal atmospheric-pressure, any liquid, by reason of its vapor-pressure, will give off vapor. As an illustration of this fact, a pan of water will gradually evaporate in a warm room, the atmosphere of which is not already saturated, yet to boil the water requires a temperature of 212 deg. fahr. At the boiling-point, the vapor-pressure is equal to the atmospheric pressure. You will often note vapor coming out of a radiator when the filler-cap is open, although the temperature of the water is not more than 180 deg. fahr. So, it is possible to remove practically all the gasoline diluent at a somewhat lower temperature than would be supposed to be possible. This means that the time-element is a large factor in eliminating the dilution. A lower temperature for a longer time will accomplish nearly the same result as a high temperature for a shorter time. Temperatures of the oil lower than 180 deg. fahr., however, seem to have very little effect at atmospheric pressure.

Cracking of Lubricating-Oil Into Gasoline

Another question: Will not the lubricating-oil crack and be converted into gasoline, thus eliminating part of the oil? This is possible but will seldom if ever happen, for a temperature of at least 650 deg. fahr. at atmospheric pressure is required to crack oil into gasoline, and there is not much danger of the oil ever reaching so high a temperature. Oil is a very poor conductor of heat, so that, in order that the oil may reach a certain temperature, the container must be considerably hotter.

The specific gravity is not a dependable indication of the amount of diluent in oil. This is quite obvious, as oil diluted with 20 per cent of kerosene will not have the same specific gravity that it would have if diluted with 20 per cent of light gasoline.

With this type of rectifier, in which the exhaust-gases are in a jacket surrounding the distillation-chamber, there is very little difference between the temperatures in winter and in summer. The difference in temperature when the engine is running at slow speed and at high speed is much greater and, in this case, is partly compensated for by the faster oil flow through the distillation-chamber as the speed of the engine and the suction from the carbureter increase.

Advantage of Forcing Oil Over Suction

The method of forcing the oil into the rectifier through a bypass from the oil-pump has some advantage over the use of suction alone. The suction-pipe, when an oil-pump is not used, must be attached to the intake manifold. The suction or vacuum in the manifold is greatest when the engine is idling or running slowly, and is very much less when the throttle is wide open; whereas, with the oil-pump, the pressure increases somewhat as the speed of the engine is increased, which means that the flow of oil through the rectifier is faster. The heat of the exhaust is greater as the speed increases and, when the suction or vacuum is obtained by an attachment to the carbureter instead of to the intake manifold, the suction increases as the speed of the engine increases.

The siphon is an interesting device. So far as I can find out, very little has been printed on research work on small self-priming siphons, though large ones have been used for years, especially in water-supply systems.

Their range of intermittent flow is rather wide; that is, if the siphon is properly designed, it will begin siphoning and stop, making an intermittent flow, at fairly wide ranges in the quantity of oil entering the receptacle per minute. But it has a characteristic that is very suitable for this work, namely, at a very slow flow of the liquid into the receptacle, the siphon will not prime, but the liquid, after reaching a high level, will flow out of the siphon tube without emptying the receptacle, whereas, when the flow is excessive, the siphon will act continuously instead of intermittently. This is an ideal condition, for it allows the oil to reach and to

remain at a high level in the rectifier at slow speeds of the engine in which the heat is low, and to stay near the bottom level when the flow is very rapid, the engine running fast and the heat much greater.

Rectifier Operating on the Forcing Principle

Fig. 5 shows a rectifier that works on the principle that the oil is forced from the pump into the bottom part through the tube *a* and the filter *b*, this particular filter being made of asbestos fabric. It then goes into the receptacle *c* where the exhaust-gases surround it and, when it reaches a certain level, siphons over through the siphon *d*, the gases, water vapor and gasoline vapor being sucked out through the expansion-chamber *e* into the carbureter through the pipe *f*. One point that is interesting is the amount of water that comes from the combustion-chamber. There is no question that most of the water in a crankcase comes from combustion. To see how it worked out, I recently took a heptane, which, as you know, is C_7H_{16}. If all gasoline were composed of heptane, the combustion of 100 lb. of gasoline would yield 144 lb. of water, in other words, more water than we had fuel, originally. Of course, that water must either go out through the exhaust or past the rings. Some of it does pass the rings. A great deal of water also comes from condensation, especially when a car is cold and runs into a warm garage or vice versa. The rectifier is attached to the exhaust manifold, in order to get the necessary heat.

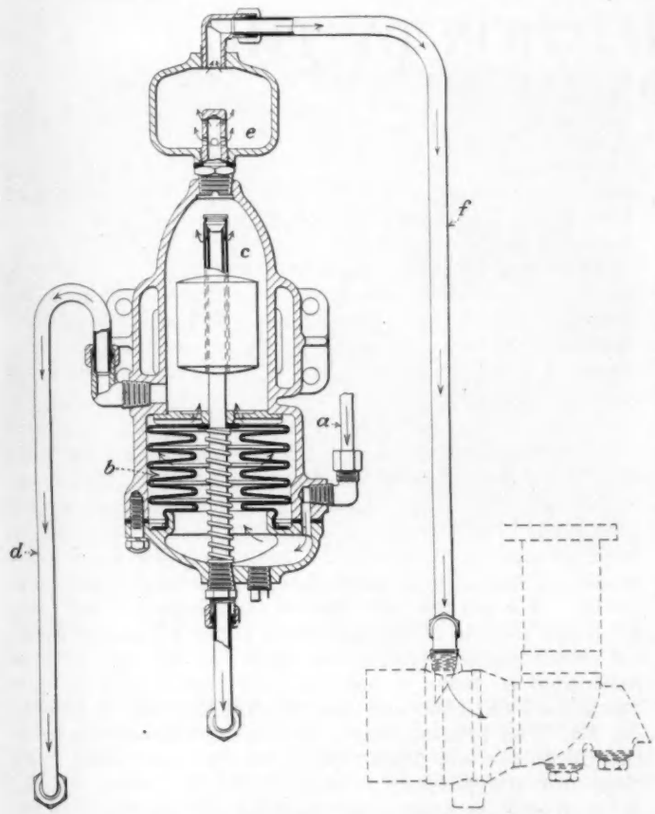

Fig. 5—Method of Operation of the Rectifier
The Drawing Shows How the Oil Flows In, Goes through the Filter, and Is Siphoned Out; also the Suction-Pipe to the Carbureter

Fig. 6 shows the installation of one of these rectifiers on a Marmon engine.

The Stutz engine, shown in Fig. 7, purifies the oil with one of these rectifiers.

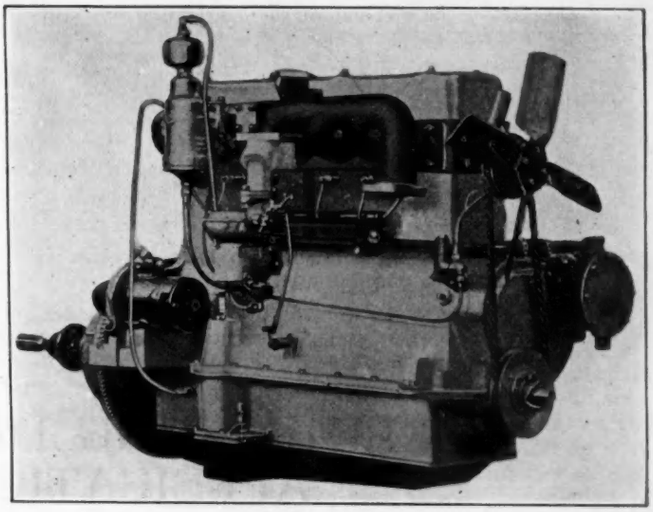

Fig. 6—Three-Way Purifier Mounted on Marmon Engine
Sometimes a Slightly Different Installation Is Used, the Oil Being Obtained from the End of the Camshaft and Taking the Same Route through the Rectifier and through the Siphons

Description of Rectifier

The rectifier is divided into two compartments. The lower compartment is provided with a large asbestos filter-sack, arranged so as to give a large filtering area in a very compact space through which the oil must pass, all the dirt being taken out before entering the upper or distillation-chamber. The distillation-chamber is exhaust jacketed. The application of heat to the oil in this chamber drives off the gasoline and water in vapor form, which is then drawn into the carbureter through the copper-tube connection. The filtered and rectified oil is returned to the crankcase by the siphon. The oil is forced into the rectifier by the oil-pump from a bypass in the oil-line. In order that the siphon may operate, the float rises, opening an air-vent connected with the crankcase and relieving the partial vacuum in the distillation-chamber. The suction line is connected with the air-horn of the carbureter.

Requirements of Commercial Rectifier

A good commercial rectifier should accomplish the following things:

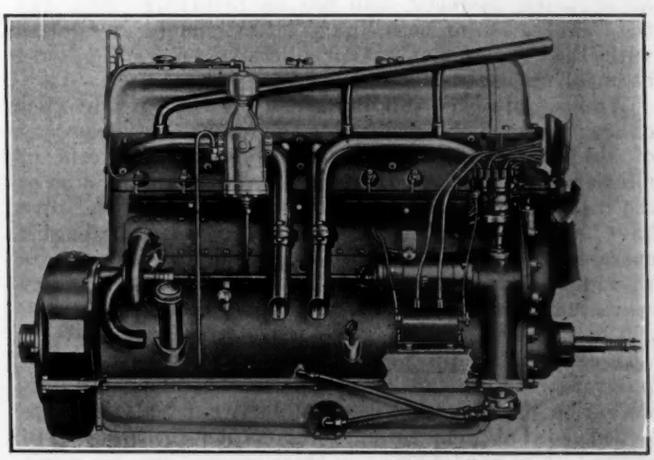

Fig. 7—Operation of Oil Rectifier on Stutz Engine
The Oil Goes through the Same Course as That Shown in Fig. 6, the Carbureter Being on the Other Side

(1) Strain the dirt out of the lubricating oil, keeping it fairly clean

(2) Distil off the diluent

(3) Distil off the water

(4) Maintain the viscosity

(5) Eliminate the necessity for draining the crankcase so often

(6) Increase the oil mileage materially

(7) Increase the gasoline mileage as a result of using the gasoline distilled off

(8) Prevent a large part of the wear on cylinder-walls and bearings by maintaining the viscosity of the oil and straining out the dirt

(9) Permit the use of lighter grades of oil the year round

(10) Prevent the freezing of the oil-pump in cold weather

(11) Keep the pistons sealed and increase the compression and power; also help to prevent fouling of the spark-plugs

(12) Prevent rusting and the forming of sulphurous acid and sludge, by eliminating the water. This also prevents etching due to the acid.

Of the rectifiers on the market, some accomplish all these things to a certain extent; others accomplish some of them extremely well. Let us hope that some day we shall see a rectifier that will accomplish all these things perfectly.

ELIMINATING DILUTION BY THE APPLICATION OF HEAT

BY J. C. COULOMBE*

ABSTRACT

WHEN eliminating dilution by the application of heat, care must be taken to control the heat so that so much heat will not be applied as to cause harmful effects. Too much heat for too long a time will form carbon and cause the oil to lose its life. A device that will prevent dilution on short drives will have difficulty in avoiding the carbonization of the oil in the summer-time when the engine is hot. Some form of heating unit that will apply heat to the device itself must be used; consequently, an attempt has been made to design a heating unit that will keep the heat unit submerged continually and will pass the oil through quickly. Views and a detailed description of such a device are given, special stress being placed on the necessity for an overflow-tube that goes entirely through the cylindrical filter. Emphasis is also placed upon the difference between driving in warm weather and in cold, particularly on short drives, which are hardly long enough to warm the engine and between which the engine again cools off.

I AGREE with Mr. Skinner and Mr. Wall in practically everything they have said as to the injurious effects of dilution and abrasives. Both have their effects. Oil that is not diluted and contains abrasives has a very injurious effect. Diluted oil that contains no abrasive, however, also has an injurious effect, but the combination of both, the greatest amount of dilution with the largest amount of abrasive, gives the most harmful results.

We have attacked this problem from the point of view of trying to do the greatest good for the greatest part of the time. Eliminating all the harmful effects of dilution and abrasives is quite a problem, on account of the various conditions of operation of an engine. We have the most dilution in cold weather, when the engine operates cold, especially during short drives. There are all kinds of driving and, if one particular condition of operation is taken care of, something at the other end will be missed.

In eliminating dilution by the application of heat, not only must the elimination of dilution be taken into consideration but the application of heat must also be controlled, so that when an engine runs hot for any length of time, as in hard driving in the summer-time, too much heat must not be applied as to go to the other extreme and cause harmful effects. The application of enough heat to oil for a great length of time is bound to form carbon and the oil will lose its life.

A device, therefore, that will have sufficient heat to be effective on very short drives and will eliminate the dilution under those conditions will have difficulty in eliminating the carbonizing of the oil under the conditions of hard driving in the summer-time with a hot engine.

THE HEATING UNIT

In eliminating dilution by the application of heat, some form of heating unit for applying heat to the device itself must be used. The formation of carbon by the intermittent application of heat is worse than if the oil were allowed to remain over a heated surface for a great length of time, or if the heating unit were allowed to drain. If a particle of metal is submerged in oil for a time and then is allowed to drain for a while, the application of heat will readily carbonize the oil. So, we have attempted to make a heating unit that would be submerged all the time and pass the oil through it quickly. As Mr. Wall has explained, it is not necessary to bring the oil to the distillation-point of any particular fraction, but the frequency with which the oil is passed through and the average of the heat will take care of the vaporization very readily.

We can go into the matter of abrasives by showing the device with which we have tried to eliminate the danger of dilution and abrasives.

Fig. 8 shows a general installation of the device. The vacuum-tank *G* is mounted on the dash and the heating unit *H* is strapped to the exhaust manifold at a convenient location, the surface being adaptable to any particular engine. One of the oil-intake lines *I* leads from the lower part of the crankcase to the heating unit; the other line *J* leads from the heating unit to the intake of the vacuum-tank. Another line *K* leads to the intake manifold from the top of the vacuum-tank and the return line *L* leads from the bottom of the tank back to the crankcase. Both fittings in the heating unit are at the top of the block, so that the surface, which fits the exhaust-pipe and is in contact with it, is always covered with oil.

OVERCOMING THE DANGER OF COKING

During the dumping cycle, when the operating chamber dumps its charge into the lower chamber, the oil

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that is left in the heating unit submerges the parts that are heated by the exhaust manifold, hence eliminates the danger of the coking of the oil in the heating unit. If the oil is heavy and of high viscosity, when the engine starts, the flow through the system is slower and allows the oil to be in contact with the heating unit for a longer period of time than when the oil is thin.

We plan on making the device so that in warm weather and in hard driving, when the oil in the crankcase sometimes reaches from 180 to 200 deg. fahr., the return oil, with the thermometer placed in the crankcase, would show an increase of heat of all the oil in the crankcase, due to the device, of approximately from 5 to 8 deg. We tried to limit ourselves to that amount in order not to carbonize the oil.

Fig. 9 shows the interior of the tank and its operation.

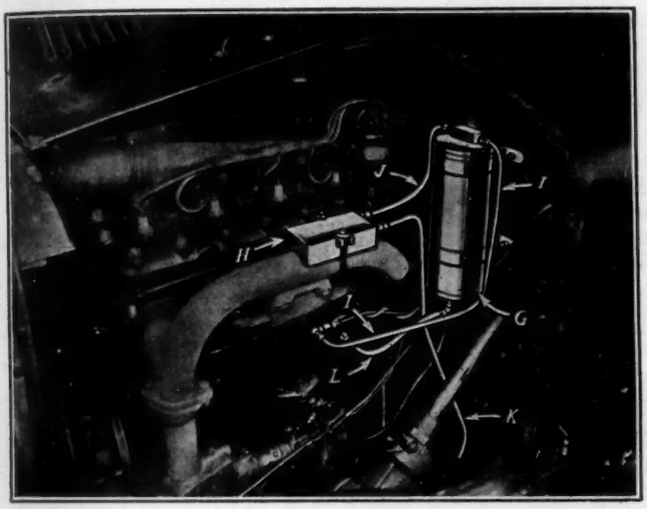

FIG. 8—TYPICAL INSTALLATION SHOWING GENERAL APPLICATION OF THE DEVICE
The Heated Surface Is Always Covered with Oil. During the Intervals of Operation of the Tank, the Operating Chamber Fills and Is Then Allowed To Dump Its Charge into the Lower Chamber

The oil enters through the intake at the upper left, the other line underneath going to the intake manifold. In the chamber at the right we have a cylindrical filter. The oil varies in viscosity and, in filtering any liquid, the viscosity and the differential pressure on both sides of the filtering medium must be taken into consideration. The greater the pressure, the finer must the filtering medium be. The same is true of viscosity. We use a filter-cloth such that medium oil at a temperature of 50 deg. fahr. will barely drop through the filter, but, as the oil becomes heated, it will go through very quickly. If it is assumed, however, that cold oil can be filtered, when the oil becomes thin, it will not take out the small particles that do most of the abrasive work. When the oil is cold, there is practically no filtration through the filter bag. If that condition is allowed to exist, the device will not be very efficient as a filter.

IMPORTANCE OF THE OVERFLOW

One point I wish to make clear. If it were not for the overflow tube that goes entirely through the cylindrical filter, the oil that is not passing through the filter, for any reason, would not go down through the overflow, at the right, back into the crankcase and be recirculated. Circulation of oil is essential on account of taking out the diluent, so as to keep the distillation and aeration in operation all the time.

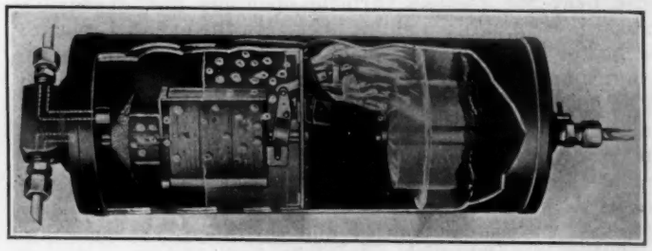

FIG. 9—STANDARD OIL AERATOR TANK
The Interior of the Tank and the Method of Operation Are Shown

Another reason that this overflow-tube is essential is that, when starting on a cold morning with oil of such viscosity that it will not go through the filter, at the first operation the chamber at the right will fill up with oil that does not go through the filter and the oil will stay there until the car has been driven far enough to raise the temperature under the hood, gradually warming the device until the oil will go through the filter.

You can readily see that, in cold weather under certain conditions of driving, a car could be driven for days with short drives without the filter's operating at all. But when the overflow is in operation, if the oil is so viscous that it does not pass through the filter, it returns to the crankcase through the bypass and thus circulates, acquiring the temperature of the oil in the crankcase, and will filter in a comparatively short time after starting the engine.

SHORT DRIVES IN COLD WEATHER

In removing dilution by heat, as I have mentioned before, the difference lies between driving in warm weather and in cold, particularly on the short drives of which we have a great many. During the last few years there has been more winter driving than ever before. Some of us drive a number of miles to our offices or shops; then the car stands until the noon hour; then again until night, long enough periods for everything to become as cold as the outside atmosphere. In many cases, we drive only a mile or so and the exhaust-pipe is hardly too warm to hold one's hand on it. That owner will have the greatest amount of trouble, because he uses the choke for the entire distance and gets the greatest amount of dilution.

The system shown in Fig. 10 is an attempt to control

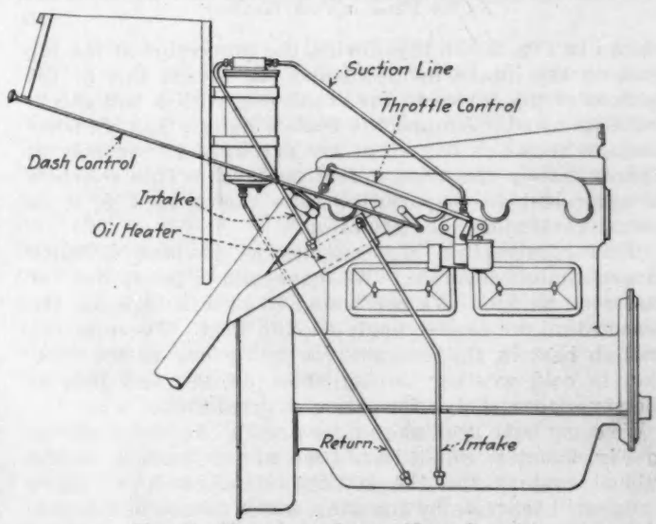

FIG. 10—METHOD OF SHUNT HEAT CONTROL
One Circuit Can Be Controlled Semi-Automatically by Means Connected With the Throttle or Accelerator Pedal Whereas the Other Can Be Placed at the Dash as a Temperature or Seasonal Control

the heat for various throttle openings and at various seasons by making a shunt back into the exhaust, placing a heater on the shunt, placing a throttle control in the shunt, and a throttle choke in the exhaust manifold. By the operation of these two throttles, nearly ideal conditions can be secured. One can be controlled semi-automatically by means connected with the throttle or the accelerator pedal, whereas the other can be placed at the dash as a temperature or seasonal control. By using one as a seasonal control and operating the other in conjunction with it, good results will be obtained. If one is intentionally left out, it will do no harm.

Simplification of Control

In the device shown in Fig. 11, we have tried to simplify the operating mechanism as well as to increase the filter area in the vacuum-tank in one device. Size for size, this device has more filter area than the device

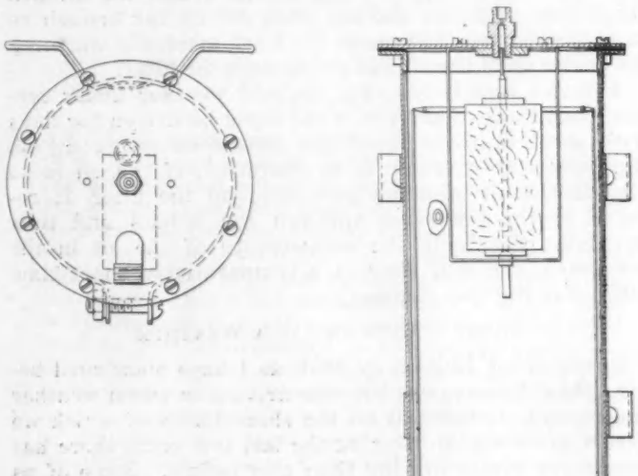

Fig. 11—Single-Chamber Oil Aerator
In This Device, the Control Has Been Simplified and the Filter Area Increased. Continuous Operation Is Obtained with the Advantage of the Filter in Cold Weather

shown in Fig. 9. In this device, the connection at the top goes to the intake manifold and the return line at the bottom of the device to the crankcase, with a ball check-valve as noted. Around the float is hung a bag, in some cases, a series of bags that are arranged to overflow at approximately the float operating level. This overflow is equivalent to the overflow-tube shown in Fig. 9, to assure continuous oil circulation.

This construction also enables us to have a much larger sludge chamber. We have laid a great deal of stress on sludge. We are bound to have sludge for the reason that we cannot apply enough heat. There is not enough heat in the exhaust-pipe to remove all the dilution in cold weather during short drives; and that is the time when sludge formation is greatest.

We could have used more filter area in the device shown in Fig. 9 but it would have been at the expense of the cubical contents of the settling chamber for sludge; sludge will separate by standing, but it cannot be filtered.

[†] M.S.A.E.—Chief engineer, Indiana Piston Ring Co., Hagerstown, Ind.

Operation of the Rectifier

Many of you have seen this device on Packard cars and practically all appreciate the way in which it functions. The effect of the third ring is apparent. The lower ring of each piston is a place from which the oil is removed. The oil is taken from the piston and carried to the rectifier, which is surrounded with a heated compartment. A series of baffles remove any oil that may be in the volatilized fuel. The gas is carried to the intake manifold and back into the engine. The oil passes through valves in the lower compartment.

In our rectifier is a thermostat that controls the heat of the oil, or the time that the oil comes into contact with the heated surface. The oil is in the compartment between the outside baffle and the outside shunt of the rectifier, when it is heated to 150 deg. fahr. The shunt is automatically opened and the oil passes into the lower compartment without being subjected to heat.

THE DISCUSSION

A Member:—What is the maximum temperature of the oil in warm weather and hard driving?

R. L. Skinner:—Under actual operating conditions, even with the thermostat operating, we have found that the heat of the oil reaches 240 or 250 deg. fahr., due to heat radiation from the top of the rectifier in the center of the unit, where the oil passes over. Under dynamometer conditions, where no allowance is made for heat radiation on the bottom of the rectifier, the temperature of the oil reaches about 400 deg. fahr.

A Member:—What is the maximum temperature?

Mr. Skinner:—Four hundred deg. fahr. on a dynamometer and about 240 deg. fahr. on the road are the hottest conditions we have experienced.

A Member:—You speak of carbon in the crankcase oil. What do you mean by that, and what is the source of this carbonaceous substance?

Mr. Skinner:—It comes primarily from the oil's splashing up on the inner side of the piston and burning.

A Member:—What importance do you attach to pour-tests?

Mr. Skinner:—Their importance concerns the circulation of oil at a low temperature, particularly in zero weather.

A Member:—If two cups of oil, one that will flow at zero and one that is solid, are stirred there will be less resistance in oil that is solid than in oil that will run, owing to the very delicate set of the oil that seems to be solid. Do you know that to be a fact?

Mr. Skinner:—No; but I know that solid oil will not flow into the pump.

A Member:—In an engine test some time ago at Purdue University, we used an oil-rectifier that operated under a wide-open throttle. We found that at the end of ½ hr. the top of the rectifier was burned out. We made the test again with another rectifier, and the same thing happened twice. We would like to find out whether that was caused by our method of operation or was the fault of the rectifier.

Mr. Skinner:—The part that failed was the heater casting and not the rectifier proper. This part is supplied by the car manufacturer. It is located in the fan blast and, under normal conditions, will not be overheated. It is not surprising, however, that, under the extreme conditions of a dynamometer test with wide-open throttle, failure of this aluminum casting should occasionally occur, as exhaust-manifold temperatures sometimes run as high as 1800 deg. fahr.

R. R. Teetor[†]:—So far as we can tell, piston-rings have

very little to do with oil dilution, as Mr. Skinner has explained. Oil dilution, however, has a good deal to do with the wearing of the piston-rings, as we have found in running some extensive tests. There is no question of the advantage of keeping crankcase-oil dilution down. The more perfectly it can be done, the longer will be the life of the engine. The wearing of the piston-rings is indicative of every wearing part of the engine.

MR. SKINNER:—I should like to hear the experience of others regarding oil temperatures.

W. C. WALL:—We have always tried, as a rule, to keep the oil temperature below 275 and near 210 deg. fahr. Under this condition, the rectifier seems to do better work.

With regard to the pour-tests of oils, many good lubricating-oils not only show a poor pour-test but become almost solid at 18 deg. fahr. I agree with Mr. Skinner than an oil, when it becomes solid, cannot be sucked into an oil-pump until it warms-up slightly. Even in zero weather, it does not take long for the crankcase to get sufficiently warm so that the oil will flow and, in the meantime, some heavy oil in the oil lines is gradually getting warm, and that keeps the pressure up fairly well for a few minutes until the oil in the crankcase becomes sufficiently liquified to be sucked into the oil-pump.

A MEMBER:—What do you estimate the maximum temperature of the crankcase oil to be, say after a hard run or a long distance?

MR. WALL:—The maximum temperature of oil that I have ever measured in the crankcase itself, when the car was running on the road, was 210 deg. fahr.; and we immediately began to redesign the crankcase because we realized that the engine was too hot. If the crankcase could remain at a temperature of 210 or 225 deg. fahr., you could get along pretty well without a rectifier, but you cannot keep the oil in the crankcase at any such temperature. In fact, the oil in an average crankcase, even in warm weather, seldom gets above 150 deg. fahr. unless the engine is on the dynamometer.

Whenever a rectifier is used, the oil is heated, returns to the crankcase and raises the temperature of the oil there; but the amount that goes through the rectifier is so small and the amount of heat-increase is so slight in comparison with the heat that the oil receives from the cylinder-walls, the bottom of the pistons and the cylinders that the greatest difference in temperature I have ever encountered from rectifier heating was considerably less than 10 deg. fahr.

A MEMBER:—Where does the sulphurous acid in the crankcase come from?

MR. WALL:—Very little of it comes from the lubricating-oil. Most of it comes from the fuel. In other words, the sulphur forms sulphur dioxide, which combines with the water to form sulphurous acid. Sulphuric acid is seldom formed because it is very difficult to change sulphurous into sulphuric acid; but sulphurous acid is sufficient to etch steel.

A MEMBER:—You think that it is in the gasoline?

MR. WALL:—Without any question, it is in the gasoline.

J. M. CRAWFORD[8]:—It is pretty well proved that it comes from the fuel, because in Birmingham, where benzol with high sulphur-content is commonly used, there is more etching of timing-chains than in any other place in this Country. I am wondering whether the action of drawing the gasoline from the retorts has a tendency to pull oil through with the gasoline and deposit it on the spark-plugs, on account of the plugs being located in the path of the incoming gasoline, and causing undue fouling of the plugs in cold weather.

MR. SKINNER:—I think that can be answered by the fact that the oil mileage invariably increases. In experimental installations we have used an additional receptacle to take care of any oil that might be carried into the intake manifold from the rectifier. In 1000 miles of operation, we got about 60 cc. of fluid, of which 85 per cent was fuel.

MR. CRAWFORD:—Was more sucked over in cold weather than in warm weather?

MR. SKINNER:—We can note absolutely no difference. In fact, we have just finished a test in zero weather during the last 10 days. Regarding the heat of crankcase oil, in a test in California, we placed a thermocouple in the oil-pan and found that in summer the oil reaches 240 deg. fahr. This was due primarily to the heat from the clutch-bands being transferred into the oil.

A MEMBER:—Do you think it possible to turn some of that oil into gas by evaporation?

MR. SKINNER:—I believe that it is possible to do so with low-flash oil. Engineers seem to have overlooked the fact that flash has a great deal to do with oil. We have made tests that show that, if the flash of the oil can be kept where it should be, the consumption of oil will not be nearly so much. In a test with a car having dilution of 20 to 25 per cent, the oil mileage was about 400 or 500 miles per gal. When the flash was increased to where it should be, the oil mileage was more than doubled.

C. W. MCKINLEY[9]:—It occurs to me that taking the oil from the back of the ring in the Skinner system would tend to cause more knocking than it would in a car not equipped with the Skinner system.

MR. SKINNER:—Engineers seem to lose sight of the fact that with our system we cannot take the oil off the cylinder-wall. The oil must get behind the ring. When drainholes are placed there, they do the same thing. If we could take the oil from the cylinder-wall we should have the groove around the cylinder-wall instead of the piston. For that reason, we block the bottom-ring groove to prevent the dilution from draining into the crankcase.

E. GEERTZ[10]:—I should like to cite a test that will also serve to answer Mr. McKinley's question. A six-cylinder motorcoach after running 30,000 miles without an oil-purifying system, was equipped with the Skinner system. The requirement was made by the manufacturers installing this system that the new pistons required by the system have the same clearance as the old pistons had at the end of 30,000 miles. The purpose was to improve engine conditions by use of the Skinner system over a long period of use. The oil mileage was increased possibly four times and the knocking was appreciably reduced. The reason for the reduction in knocking was attributed not so much to the quantity of oil on the cylinder-walls as to its quality.

O. C. BERRY[11]:—The oil-purifier people recognize thoroughly that they have a problem that must be solved. I feel sure that, in the long run, we shall get an oil purifier that will purify the oil thoroughly and will keep it sufficiently clean to be a good lubricant without interfering with the carburetion system. We have the problem daily of making engines idle down to 200 r.p.m. If we cannot do that we cannot meet competition. We

[8] M.S.A.E.—Chief engineer, Auburn Automobile Co., Auburn, Ind.
[9] M.S.A.E.—Experimental engineer, A. C. Spark Plug Co., Flint, Mich.
[10] Jun. S.A.E.—Service engineer, Skinner Automotive Device Co., Inc., Detroit.
[11] M.S.A.E.—Chief engineer, Wheeler-Schebler Carburetor Co., Inc., Indianapolis.

adjust an engine to idle at 200 r.p.m., just take our foot off the accelerator and push the clutch at the same time and expect the engine to come back to 200 r.p.m. and idle smoothly without stalling. In many cases, this is a difficult task. One of the most important factors in successfully accomplishing this result is to make certain that there are no leaks between the throttle disc and the cylinders. Even the smallest leak often means failure. Is it then to be wondered at that we object to having a large hole opened up between the throttle and the cylinders, especially when the hole sometimes delivers pure air and, at other times, almost pure fuel vapors, and changes from one to the other without any reference to carburetion?

J. C. COULOMBE:—As a manufacturer of a fuel-feeding system that is not connected with the fuel-intake manifold, but is connected to the oil-pump, we began to explain to automotive engineers, when trying to sell our devices, that one of the big advantages of our system was that the engine could idle continuously without being affected by the dumping of the tank; and they replied, "Oh, well, in these days of electric starters we do not let an engine idle very long and that is only a minor consideration."

MR. CRAWFORD:—I have been making tests on the two installations that have been described. After about 1200 miles of operation, one of them idled poorly. We immediately blamed the rectifier. We wanted to give it a fair test, so we ground the valves, tuned up the carbureter and got a couple of miles better idling than we ever did on a stock chassis.

A. C. STALEY[12]:—What happens when the rectifier depends on the manifold vacuum for operation? Does the rectifier stop operating entirely at full throttle or does it still continue in service? I should also like to have a comparison of the various methods used in this connection.

MR. COULOMBE:—Being in the vacuum-tank branch of the fuel-feeding department of our company, I have received some replies to this question that may be of interest. The idea in developing our system was to have plenty of vacuum at wide-open throttle which is not obtained with an intake manifold. With intake-manifold suction, there is sufficient vacuum at high speed to operate the vacuum-tank but not fast enough to supply sufficient fuel to keep the engine running. The worst condition is on the hills. At wide-open throttle, with a low-speed torque, the suction is not sufficient even to lift the fuel to the vacuum-tank. So, when we brought out our system, we said, "Another great advantage of this system: you never run out of fuel." What was the answer? They said: "Those conditions occur very rarely." When referring to oil-rectifiers operating from the intake manifold we can also use that as an argument.

While running at wide-open throttle, there is very little use for a rectifier unless kerosene is used; the rectifier is not really necessary for any great period of time. If you allow the rectifier or the crankcase to accumulate a little dilution when going up-hill, you will get it all back, on the principle that whatever goes up must come down.

MR. GEERTZ:—On a marine engine, when cold water is used for cooling, the need of a rectifier is apparent, because the cylinder-wall is somewhat cool in spite of the wide-open throttle.

MR. WALL:—The opinion expressed by Mr. Berry is one reason that we use an oil-pump, force the oil to the rectifier by a bypass from the oil-pump and put the suction-pipe on the air-horn of the carbureter. But I believe that the amount of gas obtained from the rectifier is so small that no carbureter will ever be affected by it. In other words, we do not get much gasoline vapor from the lubricating-oil, even when we extract it all, not so much that we can run on it. The percentage ratio to the amount of gasoline used is very small.

Idling is another feature. We know that compression is a great factor in idling. In other words, if the valves are well-ground and no gas passes the piston-rings, idling can be done much better than otherwise. Any rectifier helps to maintain the viscosity of the oil, so that the great assistance in holding compression in idling much more than counterbalances any ill effect that may be produced by the small amount of gas sucked into the manifold or the carbureter.

A MEMBER:—Mr. Wall mentioned that he uses a filter made of asbestos cloth. What effect does the asbestos have?

MR. WALL:—We tried using asbestos a couple of years ago. After making a great many experiments and getting the asbestos companies to work on it, a cloth was produced that is very soft, fine and durable. Almost anything can be done with this cloth. In softness it is between silk and cotton. The idea of using asbestos in this particular rectifier is to keep heat from affecting it. A certain amount of heat is conducted to it, as the rectifier is made of aluminum and is attached to the exhaust manifold.

A MEMBER:—Is not the gasoline that slips by the piston-rings the slow-burning part and the heavy ends? If that is true, what is gained by throwing that gasoline back into the intake manifold and trying to burn it again?

MR. WALL:—The percentage of gasoline distilled out of a sample of crankcase oil increases very materially as the temperature increases; in other words, there is considerably more of the heavy part of the fuel in the crankcase oil than of the lighter part. For instance, in a particular sample of crankcase oil, the dilution obtained, when the sample was analyzed by heating it to 300 deg. fahr., was 0.00 per cent; from 300 to 400 deg. fahr. it was 4.50 per cent; and from 400 to 450 deg. fahr., 12.00 per cent. As only a small percentage of the gasoline used goes by the piston-rings and only a small percentage of this amount goes through the oil-rectifier at one time, the amount of gasoline sucked into the carbureter from the rectifier is comparatively small in proportion to the amount of gasoline used by the engine; and, answering the last speaker, I would say that the heavy gasoline sucked from the rectifier into the carbureter is just as likely to be burned in the engine a second time as is any of the heavy portion of the fuel. We know that a great deal of gasoline having an end-point between 350 and 450 deg. fahr. must be burned. If it is not, we might as well throw away a large part of the gasoline, because a large percentage of it has that end-point.

MR. COULOMBE:—Gasoline, even if it has a low end-point, must be in a gaseous form when it leaves the rectifier and, if it reaches the cylinder in that state, is much more likely to burn than it was in the first place.

MR. BERRY:—It seems strange to me that water diluent has not been emphasized more than it has been. As I understand the subject, it seems that a little water in the oil is much more dangerous under cold-weather conditions than a great deal of kerosene. In many cars, if as much as 3 or 4 per cent of water is present in the

[12] M.S.A.E.—Associate professor of gas automotive engineering, Purdue University, West Lafayette, Ind.

oil, the screen will soon become covered with little crystals of ice and lubrication will cease. Failure of the lubricating system, due to ice, is much more dangerous than is the presence in the lubricant of even very large amounts of the heavy ends of the fuel.

One of the first things noticeable in the devices that have been described is the almost entire disappearance of water in the oil. To balance the statement I have previously made with regard to hoping some day to see a perfect rectifier that would have no tendency to interfere with the carburetion, I have seen engines with rectifiers properly installed which idled beautifully. The worst trouble comes when the engine does not naturally idle well.

CHAIRMAN G. T. BRIGGS[13]:—What do you think of the proposition of R. E. Wilson, who says that the Standard Oil Co. will soon market a prediluted oil?

MR. WALL:—Mr. Wilson's hypothesis is based on the fact that, when oil is put into a crankcase and run in an engine, the dilution will finally reach a certain equilibrium; in other words, when the dilution reaches a certain percentage, the heat of the crankcase will maintain the oil at that point of dilution. I think the idea would be fine if this hypothesis were not entirely wrong. If it were right, his oil proposition would be very good; but I have found out that, although there may be such a thing as equilibrium of the dilution in a crankcase in warm weather, when the crankcase gets fairly warm and the whole engine is rather hot, the longer an engine runs without a rectifier in cold weather, especially in short runs of from 4 to 6 miles, between which it stops and cools off, the more will the dilution increase. The curve, instead of reaching a point at which it is perfectly horizontal, shows that the dilution will increase and will continue to increase as long as the engine runs, that is, until a point is reached at which the dilution is so extremely high that it would make little difference to the parts lubricated whether it went higher or not.

[13] A.S.A.E.—General sales manager, Wheeler-Schebler Carburetor Co., Inc., Indianapolis.

OUTLOOK FOR LARGE IMPORTS

THAT the import balances in the trade of the United States during the first 4 months of this year were regarded in some quarters with apprehension and that the reappearance of an export surplus was greeted with relief are somewhat curious facts. The mercantilistic conception of trade underlying the idea of the "favorable" and "unfavorable" balance apparently dies hard. Economic conditions in Europe at the present time give some meaning to the desire for a "favorable" trade balance. But in this Country the reverse is true. If the present program of debt collection is to be carried out, a long period of import balances is very nearly inevitable. The only alternative is the investment and re-investment of American funds in Europe in ever-increasing volume; and this is an alternative that is neither to be expected nor desired, either from the European or American point of view. As long as European industry, by reason of temporary and abnormal financial conditions, remains in need of American capital, the investment of funds abroad may be considered desirable. But in the last analysis the international debts must be paid by a net excess of shipments to this Country, unless European industry is to be turned over to the ownership of aliens.

In this connection the fact that, in addition to the intergovernmental debts, vast sums of American capital have been invested abroad since the close of the war must be remembered. The annual interest charges on these loans may be regarded as an item of "invisible exports" in our foreign trade balance, since their effect will be the same as that of an actual export of goods. Interest charges alone on governmental and private debts now outstanding amount to some $500,000,000 per year. Against this sum, of course, must be placed the "invisible" items on the other side, such as expenditures of American tourists abroad, shipping and insurance charges and the like.

That an import surplus can come about in one of two ways, either by an expansion of imports or by a contraction of exports, is obvious. For this reason to note that the value of our exports in the last fiscal year declined only 2½ per cent, while the value of imports increased by 17 per cent is gratifying. Under such conditions as now exist, a tendency toward expanding imports should not be regarded with apprehension. It is rather to be welcomed as representing decidedly the easiest way out of the financial morass into which the world was thrown by the effects of war. And if some industries feel the pinch of competition, this, too, is an inevitable consequence of the method of adjustment that we have chosen and that entails upon us sacrifices which appear insignificant enough in comparison with those of our debtors.—*Guaranty Survey.*

TEACHING ENGINEERING

ALL illusions aside, do we not ask a teacher of engineering to be first a pedagog; second an auxiliary officer of administration and discipline; third his own combination secretary, file clerk and technician; and fourth—when there is any fourth—something of a creative factor in the realm of knowledge he professes? Granting that such a career is both honorable and useful, why should we expect it to appeal to engineers of distinguished ability?

Engineering is a type of activity concerned with tangible, measurable and contemporary achievement. These are the standards by which it measures its men and bestows its rewards. Teaching is an altruistic investment in the engineers of tomorrow and by its nature largely incapable of objective measurement and contemporary reward. It has its inherent attractions, but unless it is coupled with other forms of activity which open the way to tangible achievement and distinction, it can scarcely be expected to claim and hold the ablest men in the profession.

The most obvious answer is in research and kindred activities for the advancement of engineering science and art. As long as our teaching loads are as they are and all the engineering colleges combined are able to devote much less money and manpower to such activities than the investigative and development staffs of at least two single corporations, progress will be slow in investing professorships with greater prestige and drawing power through these means.—W. E. Wickenden, in a report to the Society for the Promotion of Engineering Education.

Relation of Spring-Suspension to Riding-Qualities

By F. C. Mock[1]

Dayton Section Paper *Illustrated with* Diagrams and Photograph

ABSTRACT

THIS is an analysis of spring action such as occurs on an automobile driven on a highway having bumps and depressions, a discussion of the requirements of spring-recoil checking devices, and an account of experiments made with a car on which different combinations of springs of various lengths and flexibilities were used and the distribution of weight on the frame was varied. Spring action was analyzed previously by means of small models that simulated the suspension and weight distribution of a motor-car. The compression and recoil action of springs and their relation to the travel of the car as represented by the time element are discussed. Although the more-flexible springs absorb the bumps better, it is shown that their recoil is greater unless it is damped by a shock-absorbing device.

The limitations of shock-absorber or recoil-check design are pointed out and the author asserts that a device that never allows the springs to reach their normal position stiffens the springs and increases the riding-discomfort. Obviously, the more the springs are tied-down the stiffer they become and the less capable of depression when striking a bump. That interleaf friction can be a satisfactory means of taking-up spring recoil is an erroneous belief that must be discarded, is asserted, and the greatest improvement in riding-comfort that can be made in the average car by the owner at reasonable expense is to grease the springs well, put on spring covers and automatic lubricators, and fit shock-absorbers that resist the spring recoil but do not make the springs stiffer on the bumps.

To check conclusions arrived at from analysis and casual observations, experiments were made with a car on the road. These are illustrated and described. As a result of the study and the limited number of road experiments made up to the time of writing, the author concludes that

(1) Front springs must be shackled at the front end or so mounted that full spring-travel can occur without changing the direction of the front wheels; heavier master leaves may be required for safety, and one or two rather heavy leaves above them will make the axle stable under application of four-wheel brakes

(2) Longer front springs must be used and room for spring action must be increased to at least 4 in.

(3) Internal friction of the springs must not exceed 10 per cent of the normal weight they support, and if leaf springs are used they must be lubricated

(4) Efficient devices that will check the spring recoil at the proper time and not restrict the yield of the springs on bumps or when the wheels drop into road depressions must be fitted

(5) The procedure in developing the spring-suspension of a car should be changed; the tests with new models prior to production should be made with springs of various lengths and flexibilities and with various distributions of weight on the frame. With different body-models it may be necessary to use springs of different characteristics

(6) Every effort should be made, under present limitations of passenger-car design, to locate the weight over the axles rather than between them

CLEAR conception of what happens to a car during and immediately after a road displacement, such as that caused by a bump, is the first essential to consideration of the relation between spring-suspension and riding-qualities. This much is obvious: When the wheels have reached the top of the bump the body rise plus the spring compression equals the height of the bump. With no spring action, the body receives the full upward acceleration of the bump, and, if one has not computed this, it is surprising what a tremendous upward force a slight bump will produce. On a uniform acceleration rise of only 1 in. in 2 ft. of forward travel the upward acceleration at about 20 m.p.h. car speed equals the weight of the car. At any higher speed the wheels of an unsprung vehicle would leave the surface of the road.

With any spring interposed between the wheels and the body, the upward force acting on the body is much less but is still appreciable; and the upward force is decreased as the spring is more flexible, but since a spring is merely a reservoir of energy a further action occurs; the spring yields on the bump but afterward not only returns to its former shape but tends to go as far beyond it as it had been compressed. The more flexible springs, therefore, which yield most on the bump will recoil furthest afterward. Assume a road rise of 3-in. height from one level stretch to another. With a spring that yields 1 in. the body will be raised abruptly 2 in. on the bump, and on the level stretch afterward will tend to toss up 1 in. to the normal spring-position plus a recoil of 1 in. beyond this, or a total throw of 2 in. With a spring about twice as flexible, the spring will yield 2 in. and the body will jolt up on the bump 1 in., but a recoil of 2 in. to normal position and then 2 in. beyond, or a total throw of 4 in., may ensue. For this reason some persons say that flexible springs, even though they yield more on the bump, give hard riding because of their large recoils.

Another factor to be considered, however, is the time element. As shown in Fig. 1, the quick upward jolt of the body occurs in the time the car is passing directly over the bump, and the spring compression occurs simultaneously. The spring recoil, however, occurs between the body and the axle. As springs oscillate at practically a constant rate regardless of the amplitude

[1] M.S.A.E.—Research engineer, Stromberg Motor Devices Co., Chicago.

of oscillation, the spring recoils in a fixed period regardless of car speed. This recoil usually occupies a much longer period than the time of traveling over the bump, the car traveling forward 10 ft. or more during the recoil period of the rear springs. Fig. 1 shows the relative time and distance of jolt and recoil, at a speed of 30 m.p.h. with a spring frequency of 120 oscillations per minute, which is a little more rapid than that of present-day rear springs but is not so quick as the period of the front springs that are generally used.

The time of recoil varies as the square root of the flexibility. Therefore, making the previous comparison on the basis of Fig. 1 and assuming that the first-mentioned stiffer spring has a rate of 120 oscillations per minute, we find that, on the bump, the stiff spring will jolt the body up 2 in. in 1/44 sec., the lighter spring only half as far, and the force against the passenger will be only half as great as with the flexible spring. After the bump, the stiff spring will recoil 2 in. in 25 sec., the flexible spring 4 in. in 35 sec., and each of these recoils will be at a much lower rate and affect the person of the passenger with less force than the upward jolt on the bump. Nevertheless, the more-flexible spring, although better on the bump, is at a disadvantage afterward; but by using a recoil check, or shock-absorber, the recoil can be damped as much as desired and all springs made equal so far as this recoil action is concerned. Thus it is seen that better riding requires both more-flexible springs and adequate recoil-checks or shock-absorbers.

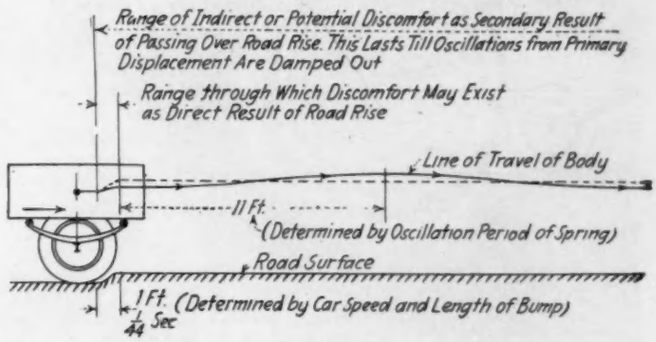
Range of Indirect or Potential Discomfort as Secondary Result of Passing Over Road Rise. This Lasts Till Oscillations from Primary Displacement Are Damped Out
Range through Which Discomfort May Exist as Direct Result of Road Rise
Line of Travel of Body
11 Ft.
(Determined by Oscillation Period of Spring)
Road Surface
1 Ft. (Determined by Car Speed and Length of Bump)
1/44 Sec

FIG. 1—HOW TIME ELEMENT AFFECTS THE LINE OF BODY TRAVEL
After Sudden Compression Due to a Road Bump, the Spring Recoils in a Fixed Period Regardless of Car Speed, and Usually the Car Travels Forward 10 Ft. or More during the Recoil Period of the Rear Springs. The Drawing Shows the Relative Time of Jolt and Recoil and the Distance Traveled during Each Period, at a Speed of 30 M.P.H. with a Spring Frequency of 120 Oscillations per Min.

SHOCK-ABSORBER REQUIREMENTS

One difficulty in designing or adapting a shock-absorber is to determine how forcefully and at what points of spring travel it shall operate. In Fig. 2 the upper four diagrams represent rather uncommon road profiles on which the full compression of the spring will be taken up in recoil. The lower two diagrams represent more common types of road inequalities upon which part of the spring recoil may be used, not in throwing the body upward, but in moving the axle downward. The body may travel along these lower profiles with less departure from a horizontal path if the recoil is but slightly restricted.

Another shock-absorber limitation is that the return of the spring to normal position must occur within a reasonably short time so that the spring will, after a bump, recover approximately its normal position and condition of flexibility before meeting another bump. One reason that is perhaps as responsible as any other for the failure of the automotive industry to use more-flexible springs has been that many types of shock-absorber *never* allow the spring to reach its normal static position but, by stiffening the spring, actually increase the discomfort of the passenger while passing over a bump, particularly with the road profiles of the lower part of Fig. 2, although they may hold the body down on the bumps shown in the upper profiles.

It should be apparent to anyone that tying down the spring will make it stiffer, yet several times I have seen a shock-absorber expert put on his instrument of this sort and try to keep a car from leaving the surface of the road on a series of short bumps and holes. In each instance the tying-down effect first tried was from 20 to 30 per cent of the weight on the spring. As this was unsuccessful, the next step was to increase the pull to 50 per cent and pull the car down still tighter, when, of course, the wheels jumped from the ground still worse. Each "expert" finally went away muttering that he could have held the car down on the road if he only had a little more pull. It did no good to suggest that he could secure the effect he was trying for if he would place solid blocks between the axles and the frame.

Another definitely erroneous belief that must be discarded before we can have better riding is that interleaf friction can be a satisfactory means of taking-up spring recoil. A slight amount, say 35 lb., of interleaf friction is desirable, otherwise the car will "dance" unsteadily. More than 60 lb. of friction per spring on cars weighing from 2500 to 3500 lb. will result in noticeably stiffer riding. The greatest improvement in riding-comfort that can be made with reasonable expense on the average privately owned car today is to grease the springs well, put on spring covers and automatic lubricators to maintain this condition and then fit shock-absorbers which resist spring recoil but do not make the spring stiffer on the bumps. Without the addition of shock-absorbers, increased spring lubrication may be unsatisfactory, particularly if the car has a definite pitching motion and does not have self-damping characteristics.

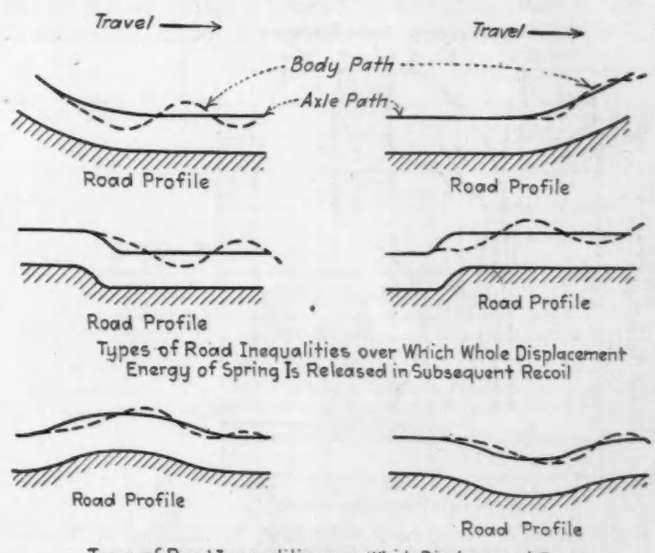
Travel
Travel
Body Path
Axle Path
Road Profile
Road Profile
Road Profile
Road Profile
Types of Road Inequalities over Which Whole Displacement Energy of Spring Is Released in Subsequent Recoil
Road Profile
Road Profile
Types of Road Inequalities over Which Displacement Energy of Spring May Be Partially Absorbed, Reducing Subsequent Recoil

FIG. 2—TYPES OF ROAD PROFILE AND THEIR EFFECT ON RELEASE OF SPRING ENERGY
Full Compression of the Spring Is Taken Up in Recoil When Passing over the Types of Bump Shown in the Upper Four Profiles. On the More Common Types of Road Inequality Shown Below, Part of the Recoil May Be Used, Not in Throwing the Car Body Upward, but in Pressing the Axle Downward. The Body May Travel along the Lower Profiles with Less Departure from a Horizontal Path if the Recoil Is Only Slightly Restricted

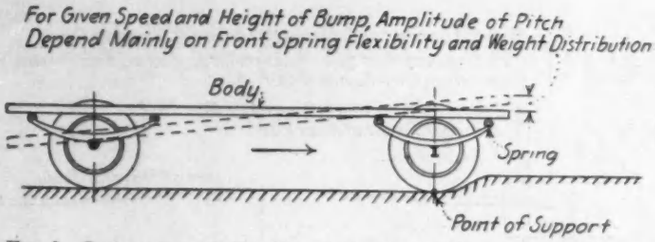
For Given Speed and Height of Bump, Amplitude of Pitch
Depend Mainly on Front Spring Flexibility and Weight Distribution
Body
Spring
Point of Support

FIG. 3—OSCILLATION OF CAR BODY WHEN THE FRONT WHEELS STRIKE A BUMP

With Weight Concentrated near the Center of the Wheelbase, the Upward Thrust of the Front Axle Tends To Rotate the Frame around the Center of the Weight, Thus Forcing the Rear End Down and Compressing the Rear Springs. Recoil-Checks Probably Will Delay Return of the Rear Springs to Their Normal Position and the Wheels Will Strike the Bump with the Springs Still Partly Compressed. If the Weight Were Concentrated Directly over the Axle, Vertical Acceleration of One End of the Car Would Have No Effect upon the Spring Position of the Other End

Two other actions of a recoil-check or shock-absorber, of the types I have seen, limit the checking effect that otherwise could be used. First, when a car encounters a depression in the road it starts to drop and therefore has a downward velocity when the wheel strikes the rise on the far side. The jolt is then perceptibly stiffer than if the same rise had been approached from a level. For any given depression of the types illustrated in Fig. 2 the drop of the car body as the wheel enters will be less as the spring is more flexible; but the same force in the shock-absorber that opposes spring recoil will oppose separation of the axle from the body as the wheels enter the depression, therefore almost any effective recoil-check will make the car seem to fall harder into holes and depressions. Fortunately it is possible, by using flexible springs, to reach a satisfactory compromise in this regard with the better types of shock-absorber that are available today.

Another limitation of the same sort exists on cars whose weight is concentrated near the center of the wheel-base. When a front wheel rises on a bump it thrusts the rear end of the car down on the rear springs, as indicated by dotted lines in Fig. 3. The frame is then down on the axle in the position where any sort of recoil-check should take maximum effect, with the probable result that the rear spring will not recover its normal position before the rear wheel strikes the bump. Consequently, recoil-checks on a car of marked pitching characteristics will make the rear end hit the bump with more force than if the recoil-checks were not fitted. This condition can be cured to some extent by using lighter front springs so that the magnitude of the initial pitching oscillation of the car will be reduced. The effect can also be reduced by moving the weight out more nearly over the axles. If the weight were concentrated directly over the axles the acceleration of one end of the car upward or downward would have no effect upon the spring position at the other end.

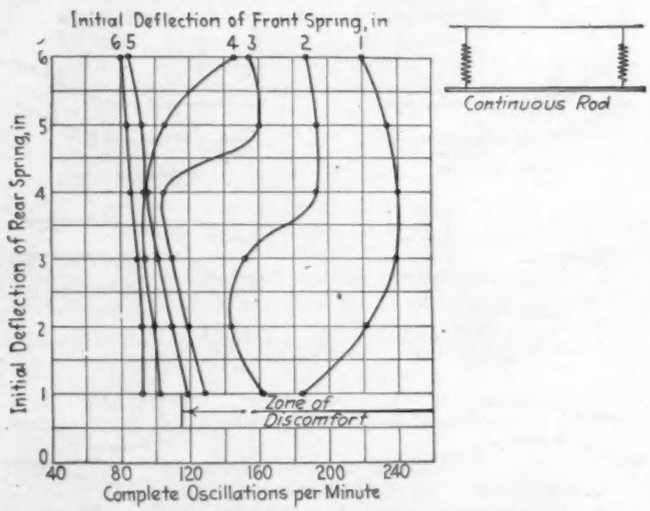
Initial Deflection of Front Spring, in
6 5 4 3 2 1
Initial Deflection of Rear Spring, in
0 1 2 3 4 5 6
Zone of Discomfort
40 80 120 160 200 240
Complete Oscillations per Minute
Continuous Rod

FIG. 4—RATE OF OSCILLATION WITH EVEN DISTRIBUTION OF WEIGHT AND DIFFERENT SPRING-FLEXIBILITIES

Flexibility of the Springs Is Stated in Terms of Initial Deflection Due to Gravity, and the Spring That Is Set in Motion To Start the Oscillations Is Designated the Front Spring. With a Very Flexible Front Spring of 6-In. Initial-Deflection, the Pitching Rate Is Between 80 and 92 per Min. with a Rear Spring of Any Deflection from 1 to 6 In., but with a Front Spring of 4-In. Initial-Deflection the Period Is Slowest with a Rear Spring of 4-In. Initial-Deflection and Most Rapid with One of 5-In. Deflection. The Change of Phase of Oscillation Corresponding with the Damping Action of a Car Is Indicated by the Wavy Portion of the Lines, as with a 3-In. Initial-Deflection Front Spring and a 4, 5 or 6-In. Initial-Deflection Rear Spring

CAR OSCILLATION OR PITCHING

When a long mass, such as an automobile, is suspended on widely separated springs, it is capable of oscillations

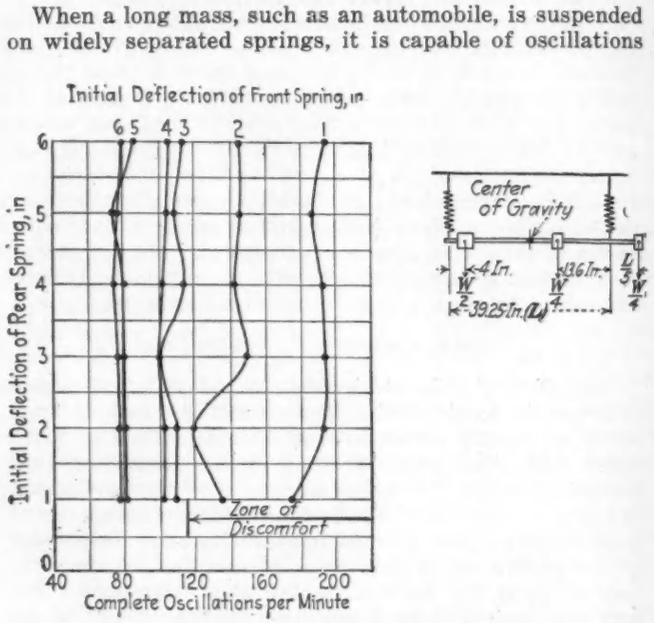
Initial Deflection of Front Spring, in
6 5 4 3 2 1
Initial Deflection of Rear Spring, in
0 1 2 3 4 5 6
Zone of Discomfort
40 80 120 160 200
Complete Oscillations per Minute
Center of Gravity
4 In.
136 In.
39.25 In. (L)

FIG. 5—OSCILLATION RATE WITH OVERHANGING WEIGHT AT REAR END

With This Unsymmetrical Weight-Distribution, Corresponding to That of a Long Car with the Engine Well to the Front and Considerable Body-Overhang at the Rear, the Pitching Rate Is Slower than with Even Weight-Distribution, and Variation of Period with Various Combinations of Spring Flexibilities Is Less Marked, Probably Due Largely to the Greater Radius of Gyration around the Center of Gravity

that, to the observer, appear to be of three different types according to how it is set in motion. In general, if the stiffer spring at one end be disturbed, the body will oscillate about a point between the springs; but if the more-flexible spring at the other end be disturbed, the oscillation will be slower and apparently about a center beyond the point of support of the stiffer spring. If both springs are disturbed in a certain way, it may be possible to cause both ends of the body to rise and fall at the same time, in a still different rate. In general, if the weight be symmetrically arranged as regards the axles, and the spring flexibilities be either closely alike or widely different, the motion will continue steadily for some time; but if the weight be distributed unsymmetrically, or the single spring frequencies or their harmonics differ by a moderate amount, the motion will pass through all the different phases mentioned, with the result in practice that it dampens out more quickly. In actual riding, the pitching motion that is most observed, in the front seat in particular, is that of the period induced by displacement of the front spring.

The rate of oscillation is slower either as the springs are more flexible or as the radius of gyration is greater. Figs. 4 and 5 show the rates of oscillation of two different weight distributions, with varying flexibilities of the springs and with the points of support 39¼ in. apart. The "front" spring is so designated because it was the one set in motion to start the oscillations. It will be noted that the flexibility of the different springs has been stated in terms of the initial deflection, or the deflection under the acceleration of gravity, as their relative deflection under upward acceleration will be proportional to this. The quickness, or rate, of the single spring-action alone is also measured by the initial deflection, the time in seconds of one such oscillation being equal to $2\pi\sqrt{}$ (Initial deflection in feet/32.2).

Referring to Fig. 4, in which the spring designated as the front spring is the one initially set in motion, it will be noted that with a front spring of 6-in. initial deflection the pitching rate is between 80 and 92 per min. with any rear spring; also, with a front spring of 5-in. initial deflection the pitching rate does not change much with any rear spring. With the 4-in. initial-depression front-spring, however, the pitching period is slowest with the rear spring of 4-in. initial deflection, and changing the rear spring to either greater or less flexibility than this increases the pitching rate. This combination of 4-in. front and 4-in. rear springs had an undamped characteristic, that is, it tended to maintain one rate of swing continuously, whereas, either with a 4-in. or 1-in. rear spring, the change of phase, which we have come to associate with damping action of a car, was more marked. In general, the wavy portion of the lines shown designates a region of marked change of phase, or damping action. This would include a 3-in. initial-deflection front-spring with a 5 or 6-in. rear spring, a 2-in. initial-deflection front-spring with a 4, 5 or 6-in. rear spring, and so on.

Fig. 5 shows a similar experimental set-up with the weight distributed unsymmetrically and a greater net-radius of gyration. The rate of pitching is slightly slower for a given flexibility of springs than that shown in Fig. 4; also the variation of period with various combinations is less marked. I believe that this absence of variation is due largely to the greater radius of gyration around the center of gravity. In practice on a car, we have seemed to observe that with a large radius of gyration the oscillations are harder to dampen out, but that an unsymmetrical weight-distribution such as that in Fig. 5 does help to dampen the oscillations. In other words, the damping characteristic can be obtained with symmetrical weight-distribution and unsymmetrical springs or with unsymmetrical distribution and symmetrical springs; and between these limits a combination can always be found that will give the damping characteristic to any given weight-distribution.

It should be remembered that a self-damping characteristic is not the only essential; it is equally important to obtain a relatively low rate of oscillation, and this involves the use of springs of at least 3-in. initial-deflection on both front and rear.

Experimental Observations of Spring Action

To check the conclusions reached previously from analysis and casual observation, a car of average dimensions was so fitted that a variety of springs, tires, weight-distributions, and recoil-checks could be used. The possible combinations are almost innumerable but thus far we have tried only those that seemed to be the principal ones. Several of these produce a standard of

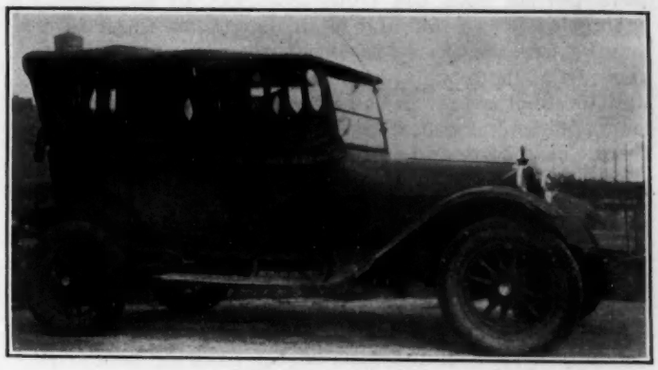

Fig. 6—Dilapidated Car Used for Experimental Work with Various Spring Combinations and Distributions of Weight

Spring Brackets to Take 36, 42, 50 and 58-In. Springs Were Fitted and the Frame Was Extended and Used To Support Cast-Iron Weights in Front and Rear. The Weights Were Moved as Desired from the Extensions to the Front-Seat and Rear-Seat Floor-Boards. The Front Springs Were Shackled at Their Front Ends and Anchored at Their Rear Ends and the Arc of Travel of the Axle Coincided with the Arc about the Rear Ball-Joint of the Fore-and-Aft Steering-Gear Connecting-Rod

riding-comfort that we thought was better than any we had previously observed. A recital of some of these experiments follows.

That the results may be susceptible of general comparison, the tire and spring flexibilities are given in terms of initial deflection and the weight-distribution in terms of gyration around the center of gravity, which in this case was very close to the center of the wheelbase. Some estimate of the friction, or recoil-check effect, is also given. These, together with the length of wheelbase, are, so far as I know, the main factors that determine the relative riding-qualities of a car.

For economical experimentation, the 2500-lb. 112-in.-wheelbase car shown in Fig. 6 was selected. It was assumed from the dilapidated state of its body and several bullet holes that this car had a hectic past and would not be particularly outraged by further indignities which it was to suffer. After a trial of its riding-qualities in the condition in which it was taken, new spring-brackets

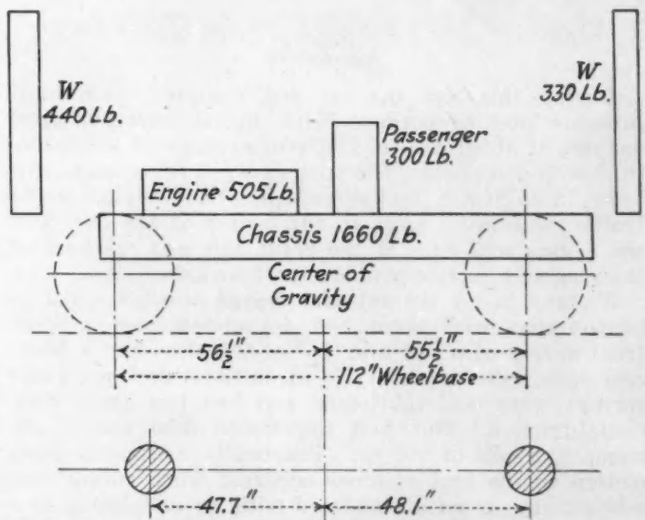

Fig. 7—Weight Distribution That Gave a Very Slow Pitching Rate with Long Front and Rear-Springs

Auxiliary Weights of 440 and 330 Lb. Respectively Were Placed on the Frame Extensions at the Front and Rear in the Positions Indicated. Front Springs 50 In. Long and of 3-In. Initial-Deflection and Rear Springs 58 In. Long and of 4⅞-In. Initial-Deflection Were Used. This Weight Distribution and Spring Combination Gave Very Soft Riding but the Oscillations, Even with Shock-Absorbers, Were Persistent and Became Annoying

were put on both the front and rear to accommodate springs of 36, 42, 50, and 58-in. length, as these several lengths were necessary to obtain the various flexibilities and initial deflections desired without exceeding a safe limit of fiber stress in the master leaf. The use of the long springs necessitated considerable extension of the frame, as shown, and these extensions were employed as supports for long cast-iron weights that were used to change the weight-distribution of the car. The spring flexibilities were selected on the basis of these weights being aboard, either out on the ends of the car or on the front and rear seat-compartment floor-boards.

The front springs were shackled at their front and anchored at their rear ends. The spring layout was carefully drawn in full size on the drawing-board with the aid of a wooden spring, so that the path described by the axle during spring travel would coincide with an arc about the rear ball-joint of the fore-and-aft steering-gear connecting-rod. Evidently our calculations were correct, for the steering was very steady; on a very bad road, with the front end tossing up and down 12 in. or more, the car maintained a steadily straight course with a light pressure of one hand on the steering-wheel. When the front end was "teetered" up and down to the limit of spring travel, the front of the front tires did not waver perceptibly. No wheel shimmy has developed thus far, although I have not given these combinations the high-speed tests I should like to, on account of winter road-conditions.

The experiments thus far were made with semi-balloon tires, inflated to about 50-lb. pressure and having about 1-in. initial-deflection under load. We plan to try high-pressure tires later.

The action of the car as first obtained was about as evil as that of any car I have ever ridden in; a jolt passed up from each pebble in the road and the passenger was kept in continual motion on the seat cushions; the car fell into each depression with a thud, had a most vicious recoil or toss on bumps 2 in. or more in height and a mean "seasick" pitch on a slightly uneven boulevard and was hard to hold on the road at high speed because of both pitching oscillations and lateral unsteadiness.

Effect of Long Flexible Springs and Shock-Absorbers

During this test the car was equipped with high-pressure tires of perhaps ½-in. initial-deflection, front springs of about 1⅝-in. and rear springs of about 2¼-in. initial-deflection. The springs were very rusty, with from 75 to 100-lb. initial-friction. The weight concentration was fairly close to the center of the car, with the engine well back of the front axle and the back of the rear seat vertically above the rear axle.

Wishing to try the extreme change possible, I put on balloon tires with about 1-in. initial-deflection, a 50-in. front spring of about 3-in. initial-deflection and a 58-in. rear spring giving about 4⅞-in. initial-deflection. These springs were well lubricated and had less than 40-lb. initial-friction. Our first impression then was of extreme softness of riding. Practically no up-and-down motion on the seat cushions occurred when riding over cobblestones or on a boulevard with an undulating surface. One brick street with a series of bumps from 3 to 5 in. high and about the same distance apart as the length of the wheelbase of the car and where we thought a car behaved well if the wheels would stay on the ground at speeds no higher than 18 m.p.h., was selected as a place to test shock-absorbers. This pavement was driven over one night in the newly equipped experimental car fitted with light shock-absorbers and with the weights far out on the ends, and we could not find the rough place because we could not tell when we were passing over it.

It then became necessary to discontinue the experiments for several weeks, with only occasional use of the car, and when we began to check its riding-qualities again, it was found to be stiff and less gentle than before. It was slightly "choppy," threw one up and down on the seat cushions, and scarcely rode better than the average car. I thought perhaps the shock-absorbers were holding the springs down and took them off, without making much improvement. The springs, which were found to be rusty, were then cleaned, greased and replaced with spring covers on them, after which they seemed to show nearly the softness we experienced in the second test.

Under these conditions, but without shock-absorbers, the car was unbearable on many different kinds of road, as it had a very slow but long recoil on a series of long bumps. Shock-absorbers of 100 and then 150-lb. maximum frictional-resistance were put on but did not adequately absorb the recoil. We then tried some that built-up to 200-lb. resistance, and found the action fairly satisfactory except that the front end seemed a little more definitely to "fall" into holes. In each case the shock-absorbers were of a type that did not hold down and stiffen the spring appreciably either by resisting the rise of the axle toward the frame or preventing return of the spring to its normal position.

How Weight Distribution Affected Oscillations

The combination of 50 and 58-in. springs was tried first with the auxiliary weights at the ends of the car, a distribution shown by Fig. 7 and somewhat extreme for a passenger car. With this combination the pitching motion was very slow, about 60 oscillations per min., but insistent even though the shock-absorbers held the motion down to small magnitude, and after a short time it became annoying. Other than this, the car rode well. Sometimes, on taking corners fast, it seemed a bit slow in answering the steering-wheel, probably due to its large amount of inertia. To my surprise, it did not act particularly badly on slippery pavement as regards skidding.

The auxiliary weights were then moved to the center, as shown in Fig. 8. This entirely changed the riding of the car. It lost the feeling of slow retarded pitch and took on more of the tendency to pitch that one associates with a roadster or coupe; the motion was still slow, however, about 75 oscillations per min. I never have measured a production car as sold that had a front pitching-period slower than 100 per min. A set of tying-down shock-absorbers was much more objectionable with this weight-distribution than with the previous one. Except that the pitching was somewhat insistent, the action on cobblestones, over holes, on undulating boulevard and at high speed was good. Rather peculiarly, on long swinging bumps from 10 to 12 in. high, the rear end did not seem, from the front seat, to swing as high as with the weights far out, but in the rear seat the toss seemed just enough quicker to be objectionable. With the weights far out, the rider might be swung up a long distance yet not leave the seat cushion, as the motion was slow.

Next we tried overhanging the rear weights, leaving the front weights on the front floor-boards and affecting a weight-distribution as in Fig. 9. This reduced the

front-spring initial-deflection to about 2¾ in. and increased that of the rear springs to about 5 in. Pitching with this combination was hardly apparent; it seemed to dampen-out at once. Also it felt slower, although the rate as timed was 75 per min., the same as with both front and rear weights in the car. This was perhaps natural, as the front end had not been changed much, and the front end seems to govern the pitching. Altogether, we regard this as one of the most satisfactory combinations we have found.

A combination was then tried of 42-in. front springs of about 2¼-in. initial-deflection with the 4⅞-in.-deflection rear springs and the same tires and shock-absorbers as before. The action with this was best with the weights far out on both ends. The front pitching-period was 100 per min. and the rear period 75, and there was very little tendency for the pitching to continue. From all tests that we were able to apply, this combination and weight-distribution gave us good riding as the best previous combination and far superior to that of any other car in which I have ever ridden.

Bringing the front weights to the center increased the front pitching-rate to 107 per min. and left that of the rear unchanged. The rates were about the same with the rear weights also brought inside the car. With either of these two combinations, a feeling of stiffness at the front end was apparent; the riding was more harsh over cobblestones and the car seemed to fall into holes, hitting the far side rather hard.

We now felt that we had gone past the extreme in front-spring stiffness and decided to try the effect of a very flexible front spring in combination with a rear spring that would now be known as fairly flexible. Therefore, the 58-in. springs were put on the front and the 50-in. springs on the rear. This gave an initial deflection of 4½ in. in front and 4⅛ in. in the rear. The first sensation when I began to drive the car was one of extreme serenity, particularly of the front end. Road impacts of all sorts were much less apparent. To our surprise, no objectionable effect on the steering was noticeable at speeds as high as 45 m.p.h. on a rolling road, or at the highest safe speed over bumps from 8 to 12 in. high and over a road that was full of deep chuck-holes. Riding in the rear seat, however, was not as comfortable as with other combinations, and even in the driver's seat an unpleasant "kick" was felt occasionally when the rear wheels passed over sharp bumps. Also, the rear seat seemed to have gained in liveliness for the same recoil-check stiffness as was used with the other springs. This was true either with the weights on the floor-boards or with the rear weights overhung at the back, which last arrangement reduced the front-spring initial-deflection to 3¾ in. and increased that of the rear springs to about 4¼ in. With both front and rear weights overhung, the rear seat was less lively. The pitching action with any of these weight-distributions was not highly apparent but it was evident that the combination could have been improved as regards self-damping qualities. Lack of time prevented investigating this spring arrangement as fully as I should have liked; there is a possibility that an extremely comfortable suspension for a roadster or coupe body might be developed along these lines.

Conclusions Deduced from the Tests

From our experience in the tests that we have been able to make up to the time of writing this paper, with only a few of the possible variations, we believe it is impossible to improve the present standard of riding-quality materially so long as the limitations of current belief are accepted and previous lines of development are followed. Before a definite improvement in riding-quality can be made, the following steps must be taken:

(1) Front springs must be shackled at the front end or otherwise mounted so that the full amount of spring travel can occur without changing the direction of the front wheels. Heavier master-leaves than those of present practice, with further increase in length, may be required to assure safety. One or two rather heavy leaves above the master leaf, and which are under no stress when the spring is assembled, will make the axle stable under the application of four-wheel brakes

(2) Longer front springs must be used, and the change in appearance of the car and the possible requirement of longer parking space must be accepted as a minor price to be paid for definitely increased riding-comfort. The room for front-

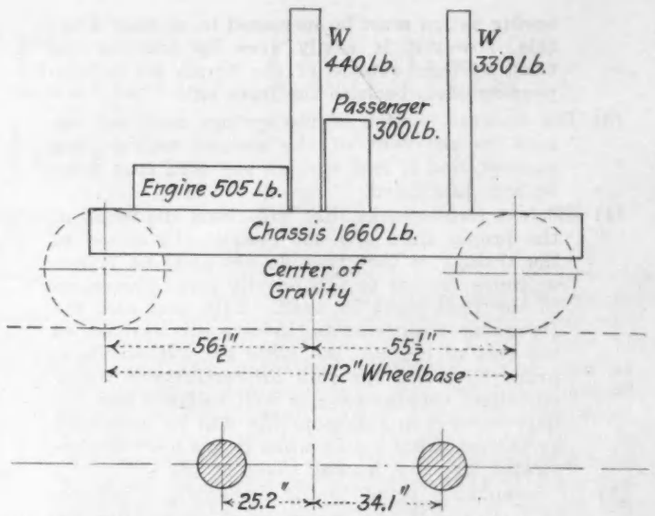

Fig. 8—Weight Distribution That Gave a Pitching Motion Like That of a Coupe or Roadster

With the Same Spring Combination as in Fig. 7, the Riding of the Car Was Entirely Changed, although the Rate of Oscillation Was only 75 per Min. The Effect of "Tying-Down" Shock-Absorbers Was More Objectionable and the Quicker Toss of the Rear Seat Was Unpleasant

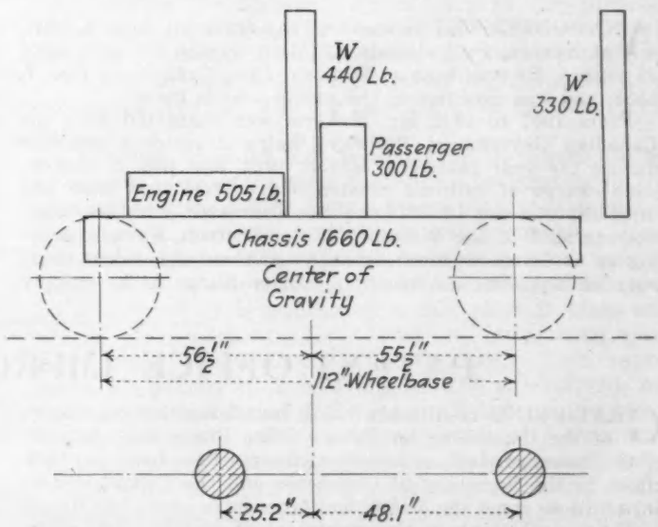

Fig. 9—One of the Most Satisfactory Weight Distributions

With Auxiliary Weights near the Center and Overhung at the Rear, the Pitching Motion Was Barely Apparent and Seemed To Dampen-Out at Once. The Oscillations Seemed Slower than with the Combination Shown in Fig. 8 but were Timed about the Same

spring action must be increased to at least 4 in.; this, however, is easily done by locating the front springs outside of the frame or by suspending them beneath the front axle

(3) The internal friction of the springs must not exceed 10 per cent of the normal weight they support, and if leaf springs are used they must be kept lubricated

(4) Efficient recoil-checks that will check the recoil at the proper time and not restrict the action of the springs so that they do not yield on bumps or cause the car to fall heavily into depressions in the road must be used. This, and also the foregoing requirements, involve an increase in the cost of the car, but since the automobile is primarily a carriage built for comfortable transportation, this increase is well justified and the improvement in riding-quality will be demanded by the motoring public when it has been demonstrated by some leading make of car

(5) Of importance equal to the foregoing, I believe, is a change in the procedure of developing the spring-suspension of a car. It is customary current practice to design the car for springs of a given length and to request spring makers to submit samples of springs to be tried that come within these limitations. From our experience, I suggest that it would be well worthwhile, when making a few experimental cars preliminary to production of a new model, to provide for the application of springs of a large range of flexibilities, either by using temporary brackets or starting with provision for a very long spring and changing the flexibilities by varying the thickness rather than the number of the leaves. These experiments should be made with the weight distributions that will exist in the complete car. If justified by the production of different body models, different springs should, if necessary, be used with each materially different weight-distribution

(6) Under present limitations of passenger-car design, every effort should be made to locate the weight over the axles rather than between them

H. C. MOSER

FOLLOWING an operation on account of a throat ailment, H. C. Moser, general manager of the Chicago Motor Coach Co. and transportation engineer for the Yellow Truck & Coach Mfg. Co. of Chicago, died at Johns Hopkins Hospital, Baltimore, on July 23, 1926, aged 43 years. Heart disease was assigned as the ailment that contributed to cause his death.

Mr. Moser was born on Sept. 1, 1882, at New York City and was educated in the public schools there, in the Long Island Business College and in Pratt Institute, Brooklyn, N. Y., supplementing this training with specialized correspondence-school courses. He was a pioneer in the transportation and the motorcoach fields, having been connected with the Metropolitan Street Railways Co., New York City, from 1898 to 1913 and with the Fifth Avenue Coach Co. from 1913 to 1923. With the former company he became assistant superintendent of transportation and, with the latter company, he was superintendent of transportation. During this entire period Mr. Moser made extensive traffic studies relating to transportation and to motorcoach operation in various cities of the United States and of Canada. In 1923 he became assistant general manager of the Chicago Motor Coach Co. and was subsequently made general manager, which position he held at the time of his death, as well as that of advisory transportation engineer for the Yellow Truck & Coach Mfg. Co.

He was elected to Associate Member grade in the Society on Oct. 23, 1925.

ALLAN GORDON McLERIE

ANNOUNCEMENT is made of the death on Aug. 4, 1926, at Kenora, Ont., Canada, of Allan Gordon McLerie, aged 37 years. He was born at Windsor, Ont., Canada, on Dec. 7, 1888, and was educated in the public schools there.

From 1907 to 1912 Mr. McLerie was connected with the Canadian Government Railways, being a resident engineer during the year preceding March, 1912, and was in responsible charge of railroad construction. From that time and until the summer of 1916, he was connected with the engineering staff of the Winnipeg Water District, Canada, serving as assistant division engineer and then as resident engineer on aqueduct construction. After being in the employ of the Walbridge Aldinger Co., Detroit, from 1916 to 1918, Mr. McLerie joined the Royal Air Force and became a flying instructor after having received thorough training in the operation and maintenance of internal-combustion engines. Subsequently, he was engaged in commercial aviation and was general manager for the Fairchild Aerial Surveys Co. of Canada, Ltd., at the time of his death.

Mr. McLerie was elected to Associate Member grade in the Society on Nov. 22, 1920. He was also a member of the Detroit Engineering Society, an associate member of the Engineering Institute of Canada, and a member of the Aero Club of Canada.

PATENT OFFICE IMPROVEMENT IS STARTED

GRATIFYING results are being manifested on the report of the Committee on Patent Office Procedure. Several of the recommendations contained therein have been put into effect by the Secretary of Commerce and the Commissioner. In addition, some important measures have been introduced in Congress looking to the enactment of suitable legislation to improve Patent Office procedure.

Recognizing the importance of five additional proposals, the Commissioner has urged that early action be taken on:

(1) The construction of a new building

(2) Providing modern equipment

(3) Increase in the technical force

(4) An increase in salaries of all scientific and technical employes

(5) A suitable amendment to the statutes reducing appeals

—Bulletin American Engineering Council.

Thermo-Vapor Engine-Cooling System

By C. H. KENNEWEG[1]

BUFFALO SECTION PAPER *Illustrated with* PHOTOGRAPH

ABSTRACT

AFTER reviewing briefly some of the major advantages of maintaining a constant high engine-operating temperature and asserting that steam-cooling is the optimum that is obtainable in engine-temperature control, as it raises the temperature quickly to a safe operating point, prevents or eliminates harmful crankcase-oil dilution and enables the engine to operate on a leaner mixture, the author describes the thermo-vapor cooling-system as a combination of the thermo-siphon system, in which boiling water is circulated rapidly through the engine-block, and a condenser system for dissipating the excess heat.

The radiator-core assembly has a top tank of large capacity from which a steam passageway communicates with the condenser, which is of conventional radiator construction but may have from 25 to 35 per cent less radiating surface. The condensate is returned to the engine-block by a positive-action pump placed as low as possible. A novel and important feature is that steam from the top of the condenser is piped through a regulating valve and a check valve and injected into the fuel mixture above the carbureter. The condensing system automatically dissipates a varying quantity of excess heat without affecting the high average operating-temperature that is maintained in the engine-block by the circulating boiling water. The system normally operates under a few inches of vacuum, which maintains an excess-temperature reserve that enables the system to absorb any heat that may be liberated after the car has been stopped.

The steam injected into the intake-manifold aids carburetion, overcomes the increased tendency of the engine to knock at the higher temperature and practically prevents the formation of carbon. The quantity of water injected in the form of vapor varies from 1 pt. to 1 qt. per 100 miles of operation, or from 2 to 5 per cent of the quantity of fuel burned, according to operating conditions. Low-grade fuels require a larger quantity; they, however, give power equal to or greater than benzol-blended fuel, provided the critical spark-time and steam injection are used. At high speeds this spark-advance may reach 50 deg.

Water should be added to the system after every 500 miles of operation under heavy-driving conditions. If poured in rapidly, it may be added until the system overflows. Part of the air is forced from the system as water is added, part is removed through the steam tube and the remaining air is constantly circulated by the pump, thereby preventing the system from becoming air-bound. Effective temperature-control under heavy engine-loads depends upon the efficiency of the water-circulating portion of the system.

A pump capacity of from 3 to 5 gal. per min. is sufficient if the operating speed is kept within reasonable limits, as the steam condensate of a 75-hp. engine is approximately 1 gal. per min.

This system has passed the experimental stage. A test car has been driven more than 20,000 miles under all conceivable operating conditions during the 18 months ended in March, 1926, and the system proved reliable and fool-proof. After a run of 5936 miles, the engine was taken down and was found to be in excellent condition. It had then been operated a total of 14,411 miles and the maximum wear of the cylinders was 0.0013 in. It was impossible to take-up any of the bearings. Only a slight carbon deposit showed on the pistons and valves. Lubricating oil used during the run of 5936 miles was tested for quality and showed a reduction of gravity from 30.0 to 27.4 deg., of the flash point from 420 to 270 deg. fahr. and of the fire test from 485 to 480 deg. fahr.; an increase in viscosity from 55 to 62 Saybolt sec. at 210 deg. fahr.; and a slight trace of dilution by water.

Deductions from the tests and experience with the system are that the average engine should operate at least 100,000 miles at a minimum service cost before an extensive overhauling is necessary and that the system will be efficient and economical in operation. The amount of carbon formed is greatly reduced, the engine warming-up period is reduced to one-third and the engine stays hot over long lay-over periods, the car mileage per gallon of fuel is increased 20 per cent or more, and the formation of sludge in the crankcase has not been evident in the test car, as all of the oil leads and drains have remained free.

THE history of steam-cooling is almost as old as the automobile industry. One early patent that was taken out in 1900 by John Imbray, of England, in the name of the Societe Industrialle des Telephones, of Paris, France, definitely establishes at least 25 years of effort to gain the benefits of high and constant engine-temperature. From then to the present, many steam cooling-systems have been worked-out, each differing from the others in details but with the object in each of accomplishing a relatively high and constant engine-temperature and the benefits to be derived therefrom.

The great interest that is displayed in steam-cooling at present is due to a more thorough appreciation of the advantages to be gained from a steam cooling-system that is properly designed and commercially usable. Consideration of the subject must embrace several factors. Lubrication involves crankcase-oil dilution, which may be illustrated by breathing on a cold pane of glass and noting the condensate, then breathing on a warm pane and noting the absence of condensate. This represents the effects of a cool engine and a relatively hot engine on the inhaled fuel-vapor. A hot engine burns a leaner mixture quickly and completely at a maximum pressure, which accounts largely for its greater efficiency.

The importance of a short warming-up period is universally conceded. The use of a carbureter choke, which is necessary to obtain sufficient gasoline vapor to provide an explosive mixture in a cold engine, can be reduced in direct ratio to the time required to accumulate a normal engine-operating temperature, with a consequent posi-

[1] President, Kenneweg Motor Corporation, Pittsburgh.

tive gain in respect of piston scuffing, engine wear and similar injurious effects. The harmful results of drawing an excessive quantity of liquid gasoline into the engine, such as washing the lubricating oil from the cylinder-walls, contaminating the lubricating oil, and forcing the engine to operate for several minutes after starting with the cylinders practically dry, or until a new oil-film is brought up, are well known.

An abnormally cool engine can be considered as operating in a partially choked condition caused by the abnormally rich mixture that is necessary for its operation. This is productive of much dilution of the lubricating oil and results in low thermal efficiency. The use of a thermostat and radiator covers provides an intermediate condition with respect of wear and thermal and mechanical efficiency.

Steam-cooling can safely be conceded to be the optimum that is obtainable in engine-temperature control, as it quickly raises the temperature to a safe operating point, absolutely prevents or eliminates injurious crankcase-oil dilution, and enables the engine to operate perfectly on a leaner mixture. The use of oil-stills and oil-filters is unnecessary with steam-cooling, as any harmful diluent that can be distilled off is positively prevented or removed, due to the high operating-temperature, either by direct vaporization or by being flashed or burned from the oil-film on the cylinder-walls. Any abrasive matter that can be filtered out of the oil must necessarily have passed through the engine and have done all the damage possible; it certainly should be kept out of the engine by means of an efficient dust-filter placed in front of the carbureter intake.

It is obvious that, as the engine temperature is increased, the volumetric efficiency is reduced, but this power loss is offset by the lower frictional losses, which are reduced possibly 5 per cent. The net result of our experience is that no appreciable difference in power output is observable.

Combination Thermosiphon and Condensing System

The particular steam cooling-system that we have named thermo-vapor cooling is practically a double system, one portion of which is a straight thermosiphon system, in which only boiling water is circulated rapidly through the engine-block, and the other portion is a condensing system to dissipate the excess heat. The radiator-core assembly consists of a special top-tank that is provided with a vertical partition which extends from side to side and is provided with a small steam-passageway at the upper edge whereby the steam generated in the engine-block is passed into the condenser section, as indicated in Fig. 1.

No change is made in the radiator cooling-section nor in the bottom tank, except that the effective cooling-area can be reduced by from 25 to 35 per cent. In addition to the parts mentioned, a positive-action pump of the gear or rotary type, preferably mounted low, a ¼-in. outside diameter copper tube connecting the steam-trap with the intake manifold through a regulating valve, and necessary rubber-hose connections, are required.

The rapid circulation of boiling water through the thermosiphon section provides a uniform high operating-temperature and the condensing system automatically dissipates the varying quantity of excess heat without affecting the average operating-temperature of the engine. The system operates normally under a few inches of vacuum, which effectively maintains an excess-temperature reserve that enables the cooling-system to absorb any heat that may be liberated after the car is stopped and renders the use of a safety valve unnecessary.

Steam Injected into Fuel Mixture

Superheated steam injected through the regulating valve into the intake manifold above the carbureter aids carburetion, overcomes the increased tendency of the engine to knock or ping at the higher operating-temperature, and practically eliminates the formation of carbon. The quantity of water used for injection into the manifold varies from less than 1 pt. to a maximum of 1 qt. per 100 miles of driving, or from 2 to 5 per cent of the quantity of fuel burned. The larger quantity of water is used under extreme power-requirements. Harry Ricardo has shown that 2.8 per cent of steam at a compression ratio of 4.65 to 1.00; 4.5 per cent at a compression ratio of 4.85 to 1.00, and 8.9 per cent at a compression ratio of 5.10 to 1.00 are sufficient to prevent detonation at full engine-load. These factors are applicable to only one grade of fuel and must vary directly with the quality of the fuel supplied. An extreme case can be cited in the official tractor tests that were made at the Nebraska State University, in which the quantity of water injected was found to be very nearly equal to the quantity of kerosene-oil fuel supplied.

Various fuels have a certain definite critical point at which spark-knock, or detonation, occurs at full-open throttle, while the spark-advance varies approximately 15 deg. with different fuels. Our tests have further indicated that the low-grade fuels give power equal to or greater than benzol-blended fuel, provided the critical spark-time and steam injection are used. The critical spark-time with steam injection at high speeds may reach 50 deg. or more.

After the system is placed on a car ready for operation, water is poured into the filler opening and runs into the tank and back to the pump, which acts as a check-valve, and then rises into the top tank, which should be made fairly large and deeper than is customary practice to carry a reserve supply of water for injection into the engine in the form of vapor. If the water is poured in rather quickly, it can be added until the system is completely full and running over. The small quantity that gets into the condenser does not affect the operation, except to build-up a slight pressure in the system after steam is formed. We recommend that the engine be started before adding water and that water be added at least every 500 miles under hard-driving conditions. It will be realized that part of the air is forced from the system through the vapor tube to the intake manifold, and that the remaining air is circulated constantly by the pump, thereby positively preventing the system from becoming air-bound.

Factors That Affect Operating Temperature

The operating temperature is affected by (*a*) pressure in the system, (*b*) density of the water in the engine-block, which density is greatly reduced by the vapor in suspension, (*c*) effectiveness of the thermosiphonal circulation, and (*d*) area of the steam port between the water tank and the condenser. This port is approximately 1 sq. in. in area for engines up to 70 hp. On the Flint Model-55 test-car an opening of this size has been sufficient to keep the maximum pressure below 3 lb. on the steepest mountain grades during the hottest days of the summer of 1925. With regard to (*c*) our experience has indicated that effective temperature-control under heavy engine-loads depends upon the efficiency

of the thermo-vapor water-circulating section. One test of about 500 miles without water circulation and mostly mountain driving, showed very bad overheating and several warped exhaust-valves. With water circulation, overheating is impossible.

Our experience with regard to pumps has been that either of two makes of from 3 to 5-gal. capacity per min. is satisfactory, provided the operating speed is kept down to reasonable limits. This capacity is sufficient to take care of an engine that develops up to 75 hp., as the steam condensate at this output is approximately 1 gal. per min. and the wetness of the steam requires a slight excess in pumping capacity. Either of these pumps, when operated as stated, and mounted as low as possible, should be effective for from 15,000 to 20,000 miles of car travel. A new pump that is being produced by the American Machine & Foundry Co. for use with the thermo-vapor system should meet every requirement and last as long as the car on which it is used.

Results Obtained with the System

The thermo-vapor cooling-system can be regarded as having passed the experimental stage, as our present test car has been driven more than 20,000 miles under all conceivable driving conditions during the 18 months ended in March, 1926, and has accomplished results well worth obtaining and been proved reliable and fool-proof in operation. To indicate some of the results obtained, the following data are submitted:

After a run of 5936 miles, the car was turned over to the Pittsburgh Flint Co.'s service station on Aug. 26, 1925, where the engine was taken down for inspection as to carbon deposit, wear of the cylinders and bearings, and the condition of the crankcase oil. In a letter, H. D. Shaukey, president of the company, wrote that, under heavy pressure, the engine did not show any wear and it was impossible to take-up any of the bearings. By measurements with the finest instrument the company's experienced engine men could hardly detect the wear on the cylinder-walls, and the engine was found to be in perfect condition for 20,000 miles more of operation. The engine had been operated a total of 14,411 miles and the maximum wear of the cylinders was 0.0013 in. The main and piston-rod bearings were in perfect condition. A light carbon deposit showed on the pistons and valves. In the two middle cylinders a thin, hard, grayish scale, undoubtedly due to road dust, was found on the cylinder-head.

At the beginning of the run, 2 gal. of Waverly No. 440 oil was put in the engine, and 2½ gal. was added during the run. The quantity removed at the end of the run was 1¾ gal. Samples of the used oil were submitted to the Waverly Oil Co. for tests as to its quality. Results of these tests were as follows:

	New Oil	Oil at End of 5936 Miles
Gravity, deg.	30.0	27.4
Flash-Point, deg. fahr.	420	270
Fire Test, deg. fahr.	485	480
Viscosity at 210 Deg. Fahr., Saybolt sec.	55	62
Dilution, per cent	0	Trace of water

The somewhat higher viscosity at the end of the run may have been due to some of the lighter elements being distilled off by the high temperature.

On Dec. 30, 1925, the test car had traveled approximately 17,500 miles. On one trip it was driven from Pittsburgh to New Jersey, New York City and Atlantic City and back to Pittsburgh, 1080 miles, in 4 days. The car has been driven from Detroit to Pittsburgh in 10 hr. 35 min.; from Pittsburgh to Atlantic City several times in less than 10 hr. 30 min., and from Pittsburgh to Buffalo and back to Pittsburgh, 476 miles, in 12 hr. 15 min., in 1 day.

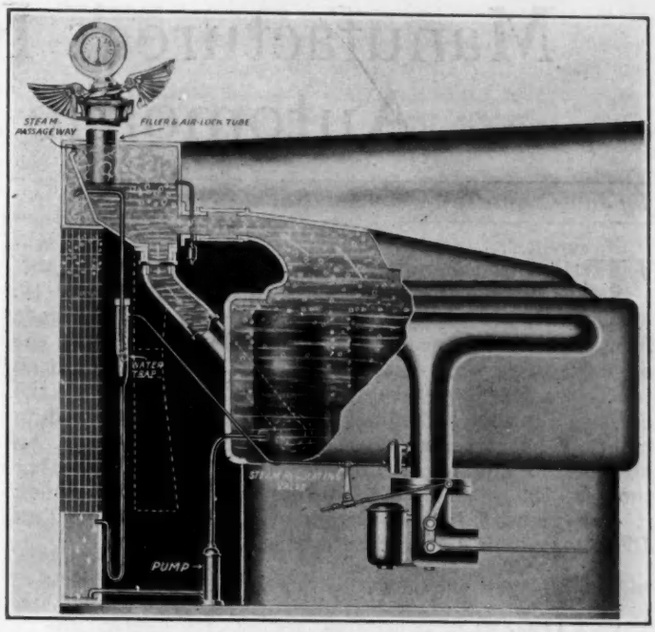

Fig. 1—Thermo-Vapor Engine-Cooling System
Boiling Water Is Circulated Rapidly through the Engine-Block by Thermosiphonal Action and Steam Passes over from the Top Tank and Is Condensed in the Condenser Core. The Condensate Is Returned to the Engine-Block by a Positive-Action Pump That Is Placed as Low as Possible. Superheated Steam from the Top of the Condenser Passes through the Water-Trap and the Small Steam Tube and Steam Regulating-Valve and Is Injected into the Intake Manifold Above the Carbureter. Excess Water in the Top Tank Is Carried Off by the Automatic-Relief Water-Valve. The System Operates Normally under a Few Inches of Vacuum, Which Maintains an Excess-Temperature Reserve That Enables the System to Absorb Heat That May Be Liberated After the Car Is Stopped

Conclusions drawn from our tests and experience with thermo-vapor cooling are that the average engine should operate for at least 100,000 miles at a minimum service cost before an extensive overhaul is necessary and that it will be efficient and economical in operation, because the system is effective, reliable, simple and fool-proof.

The amount of carbon formed in the cylinders is greatly reduced, and carbon formed under the piston heads is baked hard and any loose particles are retained in a coarse strainer.

The engine warms-up in one-third the usual time and stays hot during long lay-over periods.

A solution of pure glycerine and water is a satisfactory anti-freeze liquid. Alcohol is satisfactory also, except that it lowers the engine temperature slightly, the solution is unstable, and there is some loss of alcohol by evaporation.

Careful tests have shown an increase of 20 per cent and more in mileage per gallon of gasoline.

Ventilation of the driver's compartment is necessary.

The formation of sludge in the crankcase has not been evident in the test car after 21,000 miles of operation, as all of the oil leads and drains have remained perfectly free. Sludge in the crankcase, which usually is a combination of carbonized lubricating oil, amorphous metallic and mineral matter, water and sometimes sulphuric acid, is dangerous because of the tendency to solidify in the oil leads and drains. This is particularly true with respect to the crankcase throws, where rapid separation occurs due to centrifugal force, thereby stopping-up important leads.

Manufacturer's Reflections on the Automobile Service Field

By JOHN SQUIRES[1] AND CARL BREER[2]

SERVICE MEETING PAPER

THE discussion following the presentation of this paper at the Service Meeting held Nov. 9 and 10, 1925, in Chicago, was constituted of remarks made from the floor. In accordance with the usual practice, the stenographic report of these remarks has been submitted to the various speakers for their approval and to the authors for any additional comment that they cared to make. The corrected discussion is printed below. An abstract of the paper precedes the discussion so that those of the members who did not read the paper when it was printed in the December, 1925, issue of THE JOURNAL can use it for reference.

ABSTRACT

INVALUABLE experience gained throughout the Country by competent men engaged in "servicing" automobiles is presented specifically in a series of field notes describing reported troubles and their successful diagnosis and remedy, comments being made thereon. Factory representatives, distributors, dealers, salesmen, service organizations, repairmen and owners contribute their respective portions of the information conveyed, the intention of the authors being to demonstrate that a successful field-service organization is one which has the feeling that it is a part of the factory organization, in spirit and at heart. With this attitude of mind, problems of servicing automobiles always will appear from the simple, rather than from the complex, side. Further, the attitude of the car-owner should be one of belief that he is a part owner of the plant in which his car was built. The foregoing attitudes can all be developed through the service sales-ability of the service department.

Subjects treated specifically are indicated by the following sub-titles: Servicing Is a Field of Unlimited Opportunity; the Psychology of Service; Better Cars But Poorer Service; An Ideal Instruction Book Needed; Field Experiences; Service Salesman Needed; Why His Cars Lost Power; Taking the Owner's Statement; Brake Readjustment Not Needed; Wrong Spark-Plugs Cause Trouble; Noises, Their Cause and Cure; Bothersome Engine Noises; Warning Concerning "Pirate" Parts; Where Detonation Occurs; Clutch Troubles Analyzed; No Benefits from Special Accessories; the Special-Accessory "Game"; Generalities As to Piracy; and Common Sense Is Needed.

In the belief of the authors, it is not possible to outline a major set of rules specifying the various means of locating automobile troubles. Faith in the good qualities of cars and a proper attitude of mind will enable the difficulties to be located by the most direct route.

THE DISCUSSION

CARL BREER[2]:—Innumerable cases exist, in which work has been done in the field and the customers charged, where some simple thing has been overlooked in getting at the fundamental trouble. For example, as to valve-tappet settings, the factory engineer checks valve-settings under a wide range of driving conditions and allows for maximum differences due to expansion by providing proper valve-clearance. Instead of investigating a click that might be caused by a tappet set at proper clearance, the average mechanic or customer in the field lashes down the tappet in disregard of what can happen in consequence of eliminating the minimum clearance established by the engineering department. In city driving, perhaps the valve mechanism works satisfactorily; but, in the climbing of a long grade, difficulty is encountered simply because the fundamentals involved were neglected. As to other phases, many mechanics in the field feel that the mechanism, as received, is imperfect. Accessory salesmen and parts manufacturers sell their wares conscientiously and convey much information; in fact, they conduct educational campaigns in selling their products. The average mechanic absorbs this information in its entirety and uses it in preference to the car-builders instructions. The salesman's arguments naturally favor the products he sells and often parts are replaced in automobiles at the owner's expense due to misguidance and the fact that the mechanic has overlooked simple fundamentals.

Speaking from experience in the early days in California, our feeling at that time was to the effect that automobile builders located in the East had two grades of automobile, one that passed inspection and was kept in the Eastern territory near the plant and another that did not pass inspection and probably went to the West Coast because, when such cars reached the other side of the Rocky Mountains, they could not get back. In those days, any successful organization in California realized that if it sold an automobile it shouldered the responsibility of satisfying the owner, which made it necessary to correct manufacturing imperfections. This Western territory had some of the most successful dealers, regardless of product. They built-up organizations to cope with any situation; today, they are still successful and are making money all over the territory.

If a car succeeds in one locality and is a failure in some neighboring city, its failure is due entirely to the irresponsibility of the service organization regarding proper cooperation with the builder, who wants the service organization to feel, in a cooperative spirit, that it really is a part of the factory organization. Then, carrying this idea farther, if the service organization has the spirit of creating the proper attitude among the car owners such that each car owner feels himself to be a part of the builder's organization and that he really has an interest in the product, the organization will succeed.

SPECIAL FIELD-SUPERVISORS

QUESTION:—What size and type of field organization is used to obtain personal contact?

JOHN SQUIRES:—In the United States, we have 17 districts under supervisorships. Attached to each district is a field service-representative; the metropolitan district has two men, making a total of 18 men in this Country. Two men are in Europe and we have one man now on his way to Australia and New Zealand. Regarding the type of these men, last year they had to undergo

[1] M.S.A.E.—Director of service, Maxwell-Chrysler Motor Corporation, Detroit.

[2] M.S.A.E.—Executive engineer, Maxwell-Chrysler Motor Corporation, Detroit.

a very severe cross-examination and demonstration as to their ability to correct any mechanical trouble to which a motor-car might be subject. We examined more than 200 candidates in selecting the first 14 who qualified. We would teach them regarding the oil-filter, the air-cleaner and the hydraulic brakes, which were then new features of design, but they had to know the other standard features of automobile construction except for certain sizes, balances and things of that nature peculiar to our cars. In the first few months of the shipments of our cars, we had to send men out who would be received with open arms everywhere and who could prove their welcome was deserved. For a year or so we utilized mechanics to whom anybody could appeal, anywhere, to find out what was wrong and learn how to correct it. When everyone became generally acquainted with the car and that sort of trouble diminished to a point at which we felt it would care for itself, we began to change the men and we have a distinctly different type of man now, a type that I believe is new in the automobile business. Our 18 men now are not only as well grounded mechanically as the first men were, but they are also very able salesmen. Their job now is to have the technical foundation whereby they can never be nonplussed by any mechanical problem which comes up and then, by showing the effects of good service, to be able to lead the distributors into improving their service stations to a pitch of efficiency and a pitch of appeal to the owner at which they will be a very pronounced beneficial effect on sales. These men are high priced and are now graduating from our service work into service managerships at salaries anywhere from $400 to $600 per month. They are very decidedly worthwhile, because we would not pay that amount unless there was something in it for us, that being the sale of automobiles and the permanent satisfaction of the purchaser of our car from the time he gets it until he is ready to buy another. If there is any easy way to make him buy another, it is through the service given. We think the dealer's service-department has as much influence on sales as all the advertising and all the show-room display and sales effort that can be exerted. The type of service men used has everything to do with the result. Efficient and able service requires men of unusual characteristics, to secure the proper combination of mechanical ability with sales ability.

R. A. ARMSTRONG:—Are these men on your present force men who have developed from your former mechanical force?

MR. SQUIRES:—At present, we have only two men who were on our original mechanical force, but this does not mean that the original men have been discarded; they are placed in our distributors' organizations. We move the men along. One of the two men we still have now carries the title of service engineer. We carry him as a reserve man to go anywhere on problems that present unusual difficulties. I am using the second man as a writer of information; he prepares all the service data, gathers, in cooperation with the engineers, the things necessary for the field organization to know and is the key man on knowledge. My service engineer is a man who can go anywhere at any time to tackle anything which the local men feel is insurmountable. All the original men remain in the organization somewhere, but they are being moved along all the time because they are a great asset to us and to the dealer. After they have been at the factory from 6 to 12 months and have absorbed everything we know and digested it, we do not want to let them get away from us, after having spent so much money on their education. They are usually very welcome in a distributorship whenever we are willing to release them. Their education is expensive, but it is decidedly worthwhile and pays in the end.

QUESTION:—Do these men settle claims or make adjustments?

MR. SQUIRES:—No, they report only to the home office and make recommendations to it, excepting the Pacific coast men who do some very special work because of the distance from the factory and the expense attendant on sending men from there; otherwise, everything is reported to the home office and the adjustments are made there. Each one of these men makes a report to the home office daily; so, 18 reports come in every day each covering from one to four cases.

CAPABILITY AND COMPENSATION OF MECHANICS

QUESTION:—Has the use of flat-rate pay to mechanics resulted in securing better workmen?

MR. SQUIRES:—Our distributors who have given the flat-rate system a fair trial feel that they would under no circumstances revert to the old method of operation. They have accomplished an economic gain in both earnings and the amount of space required for service, and say that their men are much happier. I think that must be true, as it averages between 20 and 30 per cent greater earnings per man per week.* It throws out the weak man very quickly, because many of these operations are team-work operations. A man who does not know his job naturally cannot remain. It brings the shop personnel down to fewer people and in some cases it has increased the amount of work put out of that shop per working day. Numerous instances of that sort exist. Our Pittsburgh distributor was working 22 men in his shop and was losing money; he has 10 men now and according to the last figures received from him he is earning $1,200 per month. He can do twice as much work with half as many men and make money. So far as he is concerned, that is the answer. The men must be satisfied or they would not be turning out the work at that rate.

JAMES A. MACAULEY[2]:—Does he compensate his men on a bonus basis?

MR. SQUIRES:—He follows our general practice, which is to encourage distributers to give the men 40 per cent of the flat-rate price.

MR. MACAULEY:—Is that 40 per cent of the sales?

MR. SQUIRES:—It is 40 per cent of the sales price of the operation. Our flat-rate operations are calculated on a per-hour basis, making it permissible for the distributer to set an approximate hourly rate, whatever the current rate may be in that locality. In some towns it may be $1.25 per hr. and, in others, $1.50. It puts the men on a basis comparable with the local rates paid, plus something to be had from their own industrious effort and their own skill. In a great number of cases the former service-situation was altered very materially in respect to better efficiency and more satisfactory working, and greater returns came in through flat-rate operation. We have yet to find a case in which flat-rate operation is unsatisfactory. In cases in which the men feel that something will be worked out of it to their disadvantage, we encourage a partial trial, without insisting that the entire shop try it, telling several of the men that they can try the plan for a few weeks and that if they are dissatisfied they can return

[2] A.S.A.E.—Sales manager, Fredonia Motor Car Co., Worcester, Mass.

to the old method. In no case have the service men ever gone back to the hourly rate. That is a fair example of how the flat rate is accepted when it is figured out properly.

The flat rate also has a practical economic aspect. It has never been calculated on the basis of time consumed by a very efficient, highly skilled man. One must strike an average that is calculated on a fair basis. The owner will not discover how much slack there is to it; he knows, however, that he will get a certain amount of work done for a certain price. We have worked this plan out from a mass of data collected through our service stations throughout the Country. Our men spent months watching individual service-jobs and our average spare-time in the operation runs from 20 to 25 per cent, but that is still very much less than the spare time the men will use when they are doing work on a straight-pay rate. We average somewhere between the poor workman and the average workman. The man can earn a goodly sum anyway, if he is at all able and willing to work. Our special men show the workmen the necessary operations. Some men increase their earnings 20 to 25 per cent more than they are able to make on day rates.

Treatment of "Come-Backs"

MR. MACAULEY:—How do you handle "come-backs"?

MR. SQUIRES:—The work is guaranteed by the men, and it must be guaranteed by the men. Then, if anything is wrong, the workman corrects it. If an owner comes back, the man does the work a second time and if that is not satisfactory, the foreman of the shop takes him off the job.

MR. MACAULEY:—Is there a limit to the time the car is permitted to be out after it leaves the shop? For instance, there are many times when it is hard to determine whether a defect is the workman's fault or just what the trouble is.

MR. SQUIRES:—That depends very largely upon how thorough the instructions on the flat-rate work are. Operations properly studied out will almost carry a man through the motions that he is to make to do the job. About the only ground for dispute is the question of the proper diagnosis of the job, and that has been our big fight. The whole thing is easy if you find out correctly what is wrong. If only a random guess is made and that guess is wide of the mark, trouble will follow. The important thing in service work is to determine exactly what is the proper thing to be done. In general, we have little trouble due to wrong diagnosis.

Use of "Key" Men

Our present service-activity is really 2 years old, but it is only within the last 6 months that we have become enthusiastic in promoting the flat rate. Before that, we did not feel sure of our ground. We made a very thorough study of the whole service situation regarding the ability of the workmen to service the cars under efficient service-station management. The foundation of good service had to be put into decent order first but, today, it is still the big weakness because of the inadequate mechanical ability of the workmen. We need to adopt the same plan in service that is in effect in our factory and have "key" men. Starting at the top and continuing all the way down, the men know less and less of the whole picture and their information is focused down to a point at which we can have specialized men for individual mechanical operations, men who do no other work. So far as we can see, there is no other way out of it. The problem is growing, and the ability of individual workmen to service cars for all troubles is becoming less. It is no longer possible for one workman to overhaul a car entirely. The idea is to put each separate job into the hands of a certain man who knows how to do it quickly and correctly. In the factory, we determine what an operation on a part should be and show a man how to do it; then he does it day in and day out.

W. S. NATHAN[4]:—Our experience bears out Mr. Squires' statements. Most of our larger distributers use the flat-rate system and would not consider going back to hourly rates. Many of them give their workmen a bonus in the form of hours of working time. A job is figured at a certain length of time; if a man does it in less time, the difference is given him as a time-bonus. Any errors made in work done during a month are rectified by the workman who made them, and the time he uses to do such work is deducted from his time-bonus; then, he gets a bonus check figured on the fair hourly rate for his time-bonus. So, the workman penalizes himself for wrong work that he does during the month.

Phases of Piecework

DONALD BLANCHARD[5]:—One effect of piecework is rather indirect and it might result from any other plan of operation, that is, to reduce labor-turnover. One cause of the shortage of skilled mechanics is the wide fluctuations of the sales curve of the average service-station. It might vary from $5,000 in one month to $15,000 in another month, representing a big labor-turnover. Piecework seems to have had the effect in a number of cases of causing the service manager to assume the responsibility of maintaining the shop full of work; consequently, in these instances, the shop has been able to operate throughout the year with a fairly uniform force of men.

Ownership of Special Tools

QUESTION:—Do workmen employed on the piecework basis purchase special tools for their personal use to increase their efficiency?

MR. SQUIRES:—We discourage that practice, preferring that the service stations provide their own general equipment. The mechanic has only the ordinary tools available for his personal use; otherwise, when a workman leaves he would take the tools with him and that would delay the service.

MR. MACAULEY:—A growing tendency to furnish the mechanic with needed tools, instead of allowing him to bring in a miscellaneous collection of tools, seems to exist. Some workmen think that because they bring in a tool-box filled with tools they are considered to be first-class workmen.

A. E. NAFE[6]:—We find that the special tool-equipment which the shop has is of considerable interest to the mechanics.

Our experience generally with the flat-rate system has been very successful. Neither the men nor the dealers would care to discard it. While it possibly has not resulted in getting better men into the shop, we feel that it has in many cases made better men of the men already in the shop, particularly in our ability to apportion the labor; for instance, to put the man who likes to work on electrical equipment on that part of the work. In some instances we have found the flat-rate system like a two-edged sword. Where it was necessary to decrease the rate to the public, we have occasionally found opposition

[4] Jun. S.A.E.—Service department, Nash Motors Co., Kenosha, Wis.

[5] M.S.A.E.—Technical editor, *Motor World Wholesale*, Philadelphia.

[6] Director of national business sales, Dodge Bros., Inc., Detroit.

of the mechanics to a decrease because they were being paid a percentage of the rates. Another minor difficulty is the tendency on the part of some of the mechanics not to do some minor but needed job because it was not written on the slip. That, however, is a case showing the need of educating the men. One important thing is that the flat-rate system seems to be developing an opportunity to make charges more uniform throughout the Country. Naturally, the rates must be regulated more or less by the living conditions in a particular town, and we know that the living conditions are higher in the cities. Theoretically, at least, that necessitates a higher rate to mechanics and, therefore, a higher rate to the public, particularly in view of the higher overhead cost of the metropolitan shop. But we are finding this offset to a large extent by the fact that, in the metropolitan shop or in the larger shops, better equipment and better facilities for doing the work are provided and there is greater differentiation of labor; so, even at the same rates, the mechanic can turn out enough more work to increase his pay considerably, and practically in proportion to the higher costs of living.

Inducements to Capable Mechanics

F. A. Bonham[7]:—Are we getting better mechanics by reason of the flat-rate system? Are we looking ahead to the future of this business in the hope that because of the flat-rate system we will induce men who are now engaged in other mechanical pursuits to come into the fold? One of the problems confronting us today is lack of intelligent mechanical thought. Is the pay high enough to induce good mechanics to come into our employ? If it is not high enough, is it not likely that we are overlooking an opportunity to thrust that fact back home in connection with our dealers' organizations and thus secure their support and acceptance of a flat-rate plan which will accomplish that result?

Is it not true also that if certain special tools are offered to the mechanics at rates at which they can pay for them it will increase the efficiency of the mechanics? We all know that the time lost in going to and from the tool-rooms must come out of the man's pay. It takes him 2 or 3 min. to go to the tool-room and return and, if he does that many times, he has soon lost an hour. Will not some one speak for or against piecework and state whether we are likely to induce the men who are not now interested but who are capable of being fine mechanics to enter the service field?

Piecework versus Flat-Rate Systems

W. E. Williams[8]:—My observation of piecework as compared with other methods has extended over a wide variety of work, not only in the field of mechanics but in that of ordinary labor, and I say that piecework has the ultimate result of widening a man's thought. Piecework creates quickness of perception from the psychological point of view. My observation is that men who work on a piecework basis develop new inventions and use less time in rolling cigarettes. Piecework reacts on the whole organization of business to produce efficiency and to develop a man's thought along the line of getting something done; it induces a workman to make good use of his time and to develop the best means of working. The best men who have come under my observation and also under my control are those who calculate not only on what they are going to do right now but what they are going to do the next hour, and they make whatever shop trips that are necessary serve a double purpose whenever that can be accomplished. For the average good of the Country at large, the piecework system would be of great benefit to everybody. Although mechanics may not come to this industry from some other industry in which they have had a primary education, because it is difficult to switch a man from one line of business to another and few people can fit themselves into different occupations without considerable effort, yet, under the incentive of piecework, which causes him to use his brains, a man will educate himself in his field and be a better mechanic than if he came from some other industry, even though he may be no mechanic at the start.

Mr. Macauley:—Our experience lately is that some able mechanics who have been working in the shops for 60 to 70 cents per hr. are now driving motorcoaches because they are getting, in some cases, as much as $250 per month. We lose such men because they are not able to make as much money in the shops as they can by driving motorcoaches. The number of mechanics who are leaving the shops and going into that type of business is surprising. They would prefer to stay in the shops and would do so if we make it an object for them, but paying them from 60 to 70 cents per hr. seems to be the prevailing rate throughout the Country and we cannot hold them at such a rate.

A Member:—The problem is to make work in our shops just as attractive as it is in some other lines of industry. We should study other lines of business and find out why they do not present similar problems or, if they have had them, how they were solved. The building trades are paying higher rates and we have lost many men to them.

Fred C. Smith[9]:—I made a special study of three types of automobile mechanic, the recruit who might be enlisted, the man who is now employed and the man who has left the industry. I asked the recruit why he hesitated to become an automobile mechanic? His answer, invariably, was: "Why should I become an automobile mechanic at $30 per week when in less time I can learn to become a brick mason and get $13 per day?" When I asked that same question of the men now employed in the service stations, and added "What is the most serious thing that you have to criticize about your employment?" the answer was, "Because I am not paid for what I do." The answer of the men who had left the automobile industry for some other pursuit was, "I can make more money some place else and be more independent."

I reached the conclusion that if we have flat rates so that these men are somewhat independent in the shops and are paid for what they do, it will help wonderfully toward keeping service-station men satisfied. I am sure that the flat rate is better than the hourly rate, and that a large factor in the future development of service-station personnel will be to pay the flat rate and help the men to enter into the spirit of the service station and become a part of it.

J. W. Lord[10]:—It pays to provide each mechanic with the hand-tools particularly adapted to the car he is going to service. If a study is made of those tools, it is possible to pick out a set of tools that will do the work, as well as to develop a box in which to carry the tools so that each tool has its place and each man has an opportunity

[7] A.S.A.E.—General manager of parts and service division, Durant Motors, Inc., New York City.

[8] M.S.A.E.—Chief engineer, American Federal Wheel Co., Milwaukee; consulting engineer, American Steel Foundries, Chicago.

[9] A.S.A.E.—National director of automotive trade schools, international committee of the Young Men's Christian Association, New York City.

[10] M.S.A.E.—General manager of service department, Harrolds Motor Car Co., Long Island City, N. Y.

to have each tool available. As to developing mechanics by means of the flat rate, I believe Don F. Hastings, of Williams & Hastings, Inc., Detroit, is one of the first men who adopted piecework in the service-station shops. He says that he went one step farther and developed a scheme whereby his force was split into two opposing teams that entered into a contest. The captains of the two teams were the two men who earned the most money for any 2-week period. They chose sides and the side that produced the greatest value of work had a bonus of 5 per cent added to each man's pay. He said that the difference between the scores of the teams could be covered by $10, that the captains, with one or two exceptions, were different men each time and that the personnel of the teams was varied. The effect of those teams must have been to establish a very decided incentive for each man to show another fellow on his team the best way to do a job. There was a great interchange of thought, and a decided element of training existed in the shops.

MR. NATHAN:—Possibly, due to the fact that the factories have used the team system and the piecework system longer than the service stations have, we can gain by their experience. We have used the time system on some of our assembly lines and it has worked out well because the line is not jammed at any particular point, the production going along at a fairly uniform rate. The point just made, that men will help one another, is brought out noticeably there; one will find men helping one another and lining-up their work to get everything ready for the material as it comes along. It seems to expedite things greatly and to keep everything going smoothly all over the shop, and every one seems to be satisfied because the team, as a unit, is earning more money than it would earn otherwise.

Regarding service tools, Mr. Squires' ideas fit in well with ours. Our shops will supply the special tools peculiar to the particular car the men are servicing but, as an incentive to earn more money under the flat-rate or the team system, this point is applicable to both. The men require high-speed wrenches and special standardized service-tools. The shops are called upon to get these tools for the men, and most of them are glad to furnish them to the men at cost, thus giving them a further incentive to earn more money; the men seem glad to secure special production-tools for special production-work or for service work, as the case may be. So, I think we are developing men who are more interested in providing themselves with labor-saving devices, both as regards tools and shop equipment, and men who are really looking ahead and planning their work in advance so they can do it with the least expenditure of time.

COMPLETE VERSUS SEGREGATED SERVICE

QUESTION:—Is it desirable to render complete automotive service in the one establishment, or would it be better to go to the other extreme, and have specialty shops for each class of service?

MR. LORD:—If, for example, something goes wrong with the ignition, and very few companies make their own ignition equipment, I think the average owner would ask that the equipment be taken care of at the service station. To send an owner away from a service station to have the ignition or the battery repaired is a mistake.

MR. BONHAM:—That raises another big question, that of the cost of operating a service station today, which is higher than it was a few years ago. The tendency toward higher operating costs is dominant, leaving the dealer to face the problem created by the depleted value of the dollar. The future of the business demands that service stations be maintained for the complete servicing of the product, whether that be a battery or anything else. The manager who maintains a proper establishment is entitled to any profit that may be derived from service work on all car units. As time goes on, dealers will begin to take the specialized work on themselves anyhow, whether we want them to do so or not. In a small Texas town they have a slogan, "When you buy the car that I sell, you need not go any place else," and it is a good slogan.

MR. MACAULEY:—I favor having service stations maintained by the distributer who services the product. Some equipments are not hard to service, and money can be made on servicing such equipment. If we limit our distributers say to the bare engine, the transmission and the rear axle, those units are so well developed today that they require but little service work, and the distributers will still maintain large organizations and cannot pay expenses. On the other hand, it does not follow that an owner wants to have each part of his car fixed in some different shop. The owner today will insist that the manufacturer who sold the equipment to him must service it for him. The distributer who spends considerable money to carry parts in stock and who maintains the proper organization is entitled to some of the profit the other distributers are making. The salesmen sell the parts on which they can most easily make a considerable amount of money. In some instances, the distributer is left to sell those parts on which there is little or no profit. It is a big question, but I think the time is coming when the manufacturers will have to support their distributers better than they have done. We do not want to put the servicing departments of the equipment manufacturers out of business, but our distributers must be maintained.

MR. LORD:—Time is an element. If a car needing several different repairs is brought to our service station, one job can be made of it. We make a practice of doing that so far as possible and an owner need have his car out of service, say, ½ day only; but if he had one thing done at a time and went to several different establishments, it might take several days to accomplish the same result.

The Development of the Wright Whirlwind Type J-5 Aircraft-Engine

By E. T. Jones[1]

Aeronautic Meeting Paper *Illustrated with* Photographs, Charts and Drawings

ABSTRACT

CONFINING his subject matter strictly to a discussion of the Wright Whirlwind engine and its bearing on the present status of the air-cooled aircraft-engine, the author says that the type of engine specified embodies in its development two distinct forms of cylinder construction, the first having been developed by Charles L. Lawrance and the second by S. D. Heron. The application of these cylinders to the engine under discussion is outlined and the subsequent development is traced.

The development of the J-5 type of engine was undertaken in an effort to place the air-cooled engine fully on a par with the water-cooled type as regards fuel consumption. The cylinder is characterized by a hemispherical combustion-chamber, employing two valves with axes inclined at 70 deg. The valve-seats are of aluminum-bronze shrunk into the cast-aluminum head. The cylinder-barrel with integral cooling-fins and hold-down flange is screwed and shrunk into the aluminum-head casting. Among the advantages claimed for this cylinder over the Lawrance type of cylinder are superior head-cooling due to the larger fin-area provided by the hemispherical combustion-chamber and the relatively large space between the valve-ports; the superior barrel-cooling due to the integral steel-fins, which avoids the necessity of conducting the heat across a thermal gap between the aluminum barrel and the steel liner; the high fuel-economy presumably due to the excellent combustion-chamber shape and to the efficiency of the valve cooling; greater strength and ability to withstand abuse due to the hemispherical shape of the combustion-chamber and the superior cooling; and remarkable freedom from detonation presumably due to the combustion-chamber shape, valve cooling and spark-plug position. The shape of the combustion-chamber is also said to offer the further advantage that relatively large valves can be employed without unduly crowding the valve-seats together at the center of the head.

Cooling efficiency and fuel consumption are considered and the results of endurance tests of the J-5 engine are stated. Briefly, the engine was subjected to a 50-hr. test under full throttle at 2000 r.p.m. and showed a fuel consumption of 0.508 lb. per hp-hr.; to a 50-hr. test under full throttle at 1800 r.p.m., in which the fuel consumption was 0.458 lb. per hp-hr.; and to a 50-hr. test while supercharged, developing 295 hp. at 2150 r.p.m. and showing a fuel consumption of 0.510 lb. per hp-hr. Domestic aviation-gasoline was used in the foregoing tests. The author believes that the results of these endurance tests place the air-cooled engine definitely on an equal footing with the best water-cooled engines and that the air-cooled engine will become the standard of comparison. His final conclusion is that the development of the air-cooled engine will advance with the utmost rapidity during the next 3 years, since there is still room for great improvement in all respects including specific weight, power output per cubic inch, cooling capacity, durability, and facility of production.

THE general considerations underlying the development of air-cooled aircraft-engines are covered by Commander E. E. Wilson, U. S. N., in a thorough and comprehensive manner in his paper on Air-Cooled Engines in Naval Aircraft. The subject is discussed therein from the viewpoints of the engine designer, the airplane designer and the airplane operator. Commander Wilson's paper brings uptodate a discussion which has been going on continuously since the advent of the airplane and summarizes the entire situation in the light of the latest developments, in both the air-cooled-engine and the water-cooled-engine fields. The paper presented herewith is stricly supplementary to that of Commander Wilson and will be confined entirely to a discussion of the Wright Whirlwind engine and its bearing on the present status of the air-cooled aircraft-engine. Inasmuch as the progress in the general development of the air-cooled engine is, to a large extent, dependent upon the development of suitable cylinder-designs, this particular phase of the subject will be dealt with to the exclusion of the problems encountered in the crankcase and connecting-rod groups, which, while they merit an equal amount of attention, are not exclusively pertinent to the air-cooled engine.

The early history of the Wright Whirlwind engine has been the subject of numerous papers; hence, it will be touched upon very briefly in this discussion, the major emphasis being placed upon the recent tests of the Wright

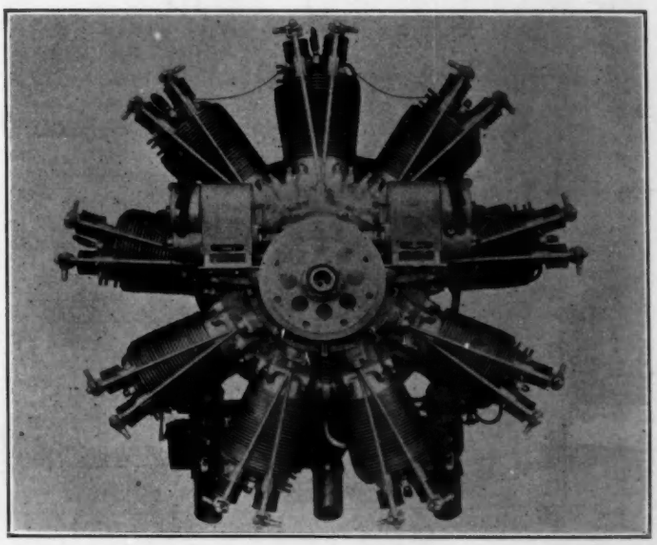

Fig. 1—Model J-1 Engine

The Displacement of the First Lawrance Nine-Cylinder Radial-Engine Was Considered Too Small To Meet the Requirements of the Navy for Training-Airplane Purposes; Hence, This Type Was Supplanted by an Engine of Larger Displacement Known as the Lawrance J-1, Which Had a 4½-In. Bore and a 5½-In. Stroke

[1] M.S.A.E.—Chief powerplant engineer, Wright Aeronautical Corporation, Paterson, N. J.

[2] See The Journal, September, 1926, p. 221.

J-5 engine, the latest addition to the Whirlwind series. In general, it can be stated that the development of the American air-cooled aircraft-engine has centered itself about two distinct types of cylinder construction, both of which have been employed in the Wright Whirlwind series. The first cylinder was developed by Charles L. Lawrance, and was brought to what might be called a successful stage toward the end of the war. The second type of cylinder was developed by S. D. Heron, while employed by the engineering division of the Army Air Service, and was first brought out during the early part of 1921.

While Mr. Lawrance's experiments in the development of air-cooled engines date back to 1915, the history of the Wright Whirlwind series can be considered as starting in 1921, when the first Lawrance nine-cylinder air-cooled radial-engine successfully passed a 50-hr. endurance-test. This engine was the first air-cooled aircraft-engine of American design and construction to complete a test of this kind successfully. With this achievement as a starting-point, the development of this series of engines has gone on continuously for the last 5 years and, to date, these engines remain the only American air-cooled aircraft-engines which have been built in production quantities and have been thoroughly tested out in actual service.

While the tests of the first Lawrance nine-cylinder radial-engine were undoubtedly successful, the displacement of the engine was considered somewhat too small to meet the requirements of the Navy for training-airplane purposes; hence, this type was immediately supplanted by an engine of larger displacement known as the Lawrance J-1, which had a 4½-in. bore and a 5½-in. stroke. These dimensions have been retained throughout

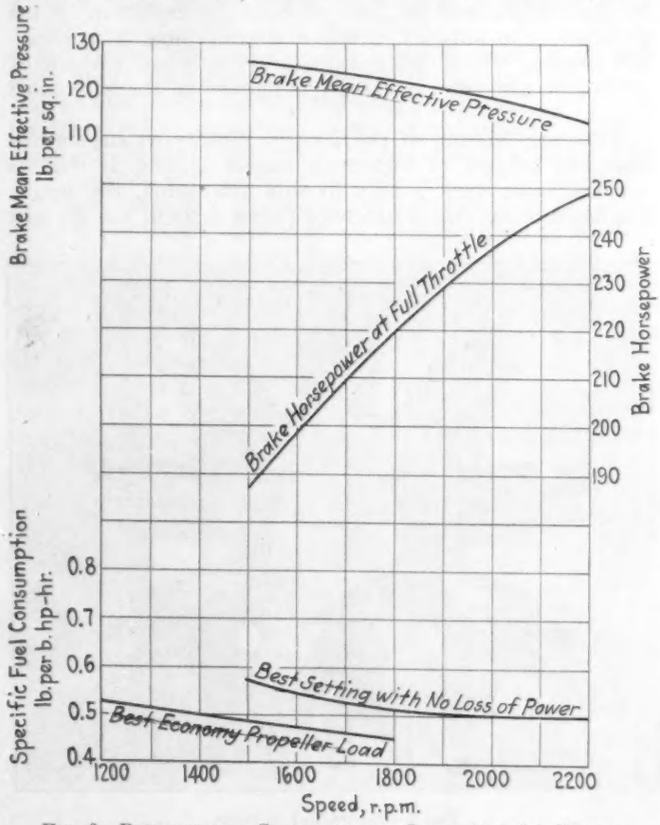

FIG. 2—PERFORMANCE CURVES OF THE LAWRANCE J-1 ENGINE
Corrected Values Are Plotted of Brake Mean Effective Pressure, Brake Horsepower at Full Throttle and Specific Fuel Consumption. The Performance Characteristics Are Evident. The Fuel Used Was Aviation Gasoline

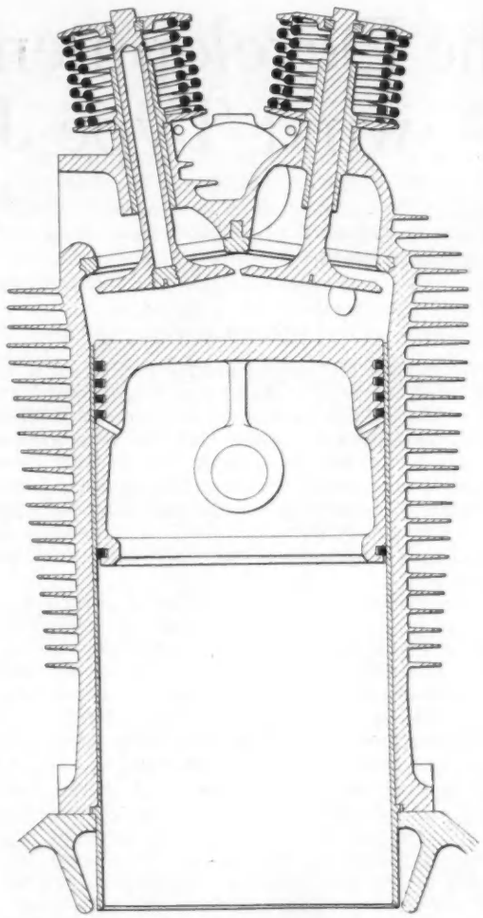

FIG. 3—CYLINDER CONSTRUCTION OF THE LAWRANCE J-1 ENGINE
The Cylinder Is Characterized by an Approximately Flat Head, Employing Two Valves. The Head and the Barrel Are Incorporated in a Single Casting of Aluminum Alloy, into Which a Steel Liner Is Shrunk. The Liner Is Held in Place by a Small Flange at the Point Where the Hold-Down Flange of the Cylinder Proper Occurs. The Valve-Seats Consist of a Spectacle-Shaped Bronze-Casting, Cast into the Aluminum Cylinder-Head

the Whirlwind series. The Model J-1 is illustrated in Fig. 1, and its performance characteristics are shown in Fig. 2.

The cylinder construction employed in this engine was largely responsible for its successful performance. Fig. 3 indicates the type of construction employed. It will be noted that the cylinder is characterized by an approximately flat head, using two valves. The head and the barrel are incorporated in a single casting of aluminum alloy, into which a steel liner is shrunk. The liner is held in place by a small flange at the same point as the hold-down flange of the cylinder proper. The valve-seats consist of a spectacle-shaped bronze-casting, cast into the aluminum cylinder-head. The cooling ability of this cylinder can be judged best by the curves shown in Fig. 2. It will be noted that the mean effective pressure and the fuel consumption are comparable with those of many water-cooled engines of the same date. Mercury-cooled valves were employed in this cylinder and proved very efficient when operating properly; however, this type was abandoned in later models, due to the extreme difficulty of sealing the valves thoroughly against leakage. Fifty of the Model J-1 engines were constructed for the Bureau of Aeronautics, Navy Department, and their success in service made such a favorable impression that

the Navy Department definitely committed itself to the policy of using only air-cooled engines in the 200-hp. class.

Subsequent Development

The subsequent development of the Whirlwind series, up to and including the Model J-4B engine, consisted mainly of a series of refinements in design. While most of these modifications were of a minor character, their effect upon the all-around durability and reliability of the engine was most pronounced. The progress in cylinder design made during this period is best illustrated by Fig. 4. It will be noted that the cast-in valve-seats were abandoned in favor of aluminum-bronze seats shrunk and rolled into position. The aluminum hold-down flange was replaced by a steel hold-down flange integral with the barrel liner, and the liner itself was screwed into the aluminum cylinder-head.

It is interesting to note that the early success of the Lawrance type of cylinder from the cooling point of view led to over-confidence in the cooling ability of this type and, as the engine was improved mechanically, there was a tendency to sacrifice cooling in an effort toward weight reduction. This tendency is readily observed by reference to Fig. 4. The result of this sacrifice in cooling-area is brought out by a comparison of the performance curves of the J-1 and the J-4A engines, (see Figs. 2 and 5). It will be noted that the fuel consumption required to develop maximum horsepower has increased from approximately 0.54 lb. per hp-hr. to the value of 0.62 lb. per hp-hr. A further result of this sacrifice in cooling-surface was a noticeable drop in the endurance of the cylinder under severe operating conditions. Cylinder failures in service became more common, in spite of numerous improvements in the details of construction such as the shrunk-in valve-seat and the steel hold-down flange.

The danger of this tendency toward a reduction in the cooling-capacity of the cylinder was quickly recognized and was promptly checked by the introduction of the J-4B cylinder, also illustrated in Fig. 4. It will be noted that this cylinder retains the general lines of the J-4A cylinder but that the fin-area has been greatly increased and, to provide better circulation of air around the head, the ports have been separated, leaving a free passage between them. To facilitate air-flow over the head further, the front spark-plug was removed from the cylinder-head and placed at the side of the combustion-chamber. The improvement effected by these changes is brought out by the performance curves shown in Fig. 6, which indicate a substantial improvement in fuel consumption accompanied by a slight gain in power. The reliability and en-

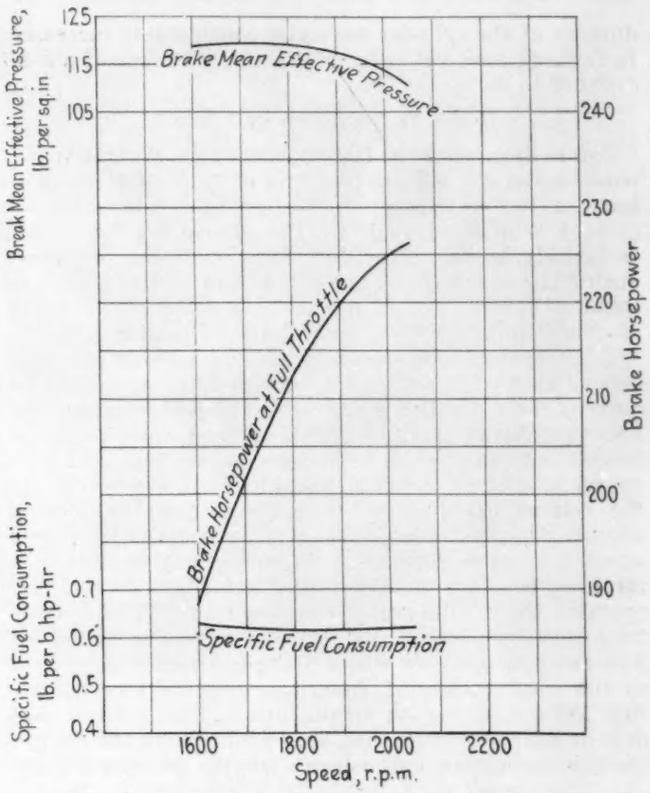

Fig. 5—Performance Curves of the J-4A Cylinder

By Comparing the Performance Curves of the J-1 Engine Shown in Fig. 2 with Those of the J-4A Cylinder Shown Here, It Will Be Noted That the Tendency To Sacrifice Cooling in an Effort toward Weight Reduction Caused the Fuel Consumption Required To Develop Maximum Horsepower To Be Increased from Approximately 0.54 Lb. Per Hp-Hr. to 0.62 Lb. Per Hp-Hr. A Further Result of This Sacrifice in Cooling-Surface Was a Noticeable Drop in the Endurance of the Cylinder under Severe Operating Conditions

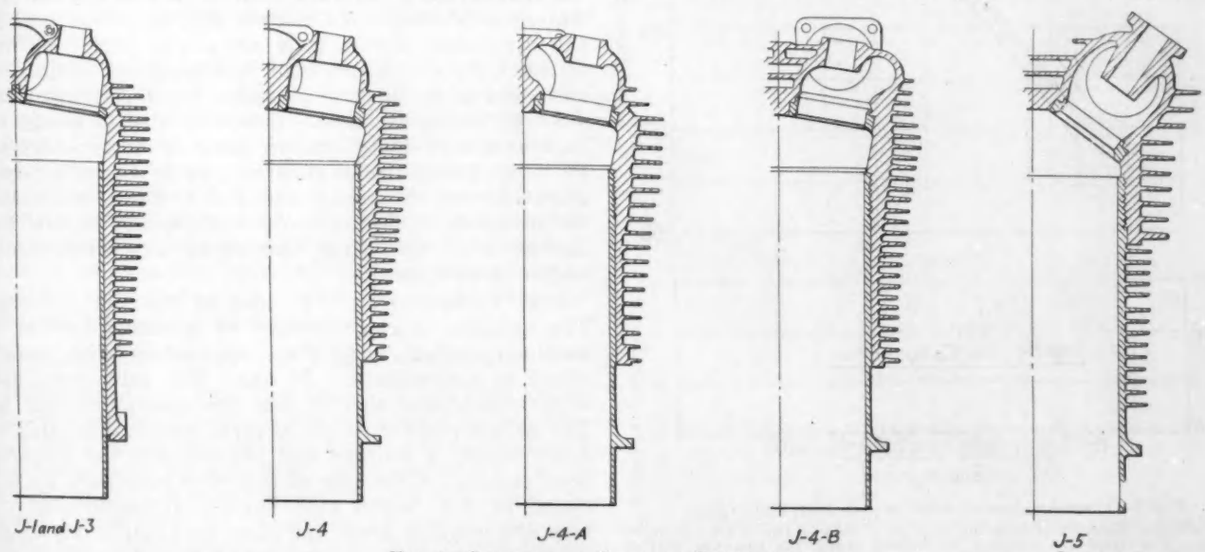

Fig. 4—Comparative Cylinder Constructions

The Progress in Cylinder Design Made during the Development of the Whirlwind Engine Is Illustrated. The Cast-In Valve-Seats Were Abandoned in Favor of Aluminum-Bronze Seats Shrunk and Rolled into Position. The Aluminum Hold-Down Flange Was Replaced by a Steel Hold-Down Flange Integral with the Barrel Liner, and the Liner Itself Was Screwed into the Aluminum Cylinder-Head

durance of the cylinder were also considerably increased. In fact, we have yet to hear of a single failure of a J-4B cylinder in service.

Results Obtained in Service

Before discussing the latest model of the Wright Whirlwind series, the J-5 engine, it is of interest to mention some of the results being obtained in service with the present Whirlwind models. The engine has been used exclusively by the Navy for training-airplane purposes during the last 4 years, and its success undoubtedly constitutes the chief factor in determining the Navy's policy of eliminating the water-cooled engine eventually.

The average flying-time between overhauls in the naval service approximates 250 hr., and we have many reports authenticated by the Navy of individual engines that greatly exceeded this time. One engine in particular has flown for more than 425 hr. without overhaul and with no replacements, except a few inner valve-springs. In the commercial-airplane field, the Wright Whirlwind engines are proving exceedingly popular. They have been adopted as powerplants for 19 commercial models, and their record for reliability in the commercial service fully confirms the results secured by the Navy. The average time between overhauls appears to be well over 200 hr. A commercial operator whose flying experience dates back to the pioneer days of American aviation received his first Whirlwind engine about Jan. 1, 1926. Since that date he has flown more than 60,000 miles with the engine. He has become an enthusiastic booster for the Wright Whirlwind engine and a firm believer in the future predominance of the air-cooled engine.

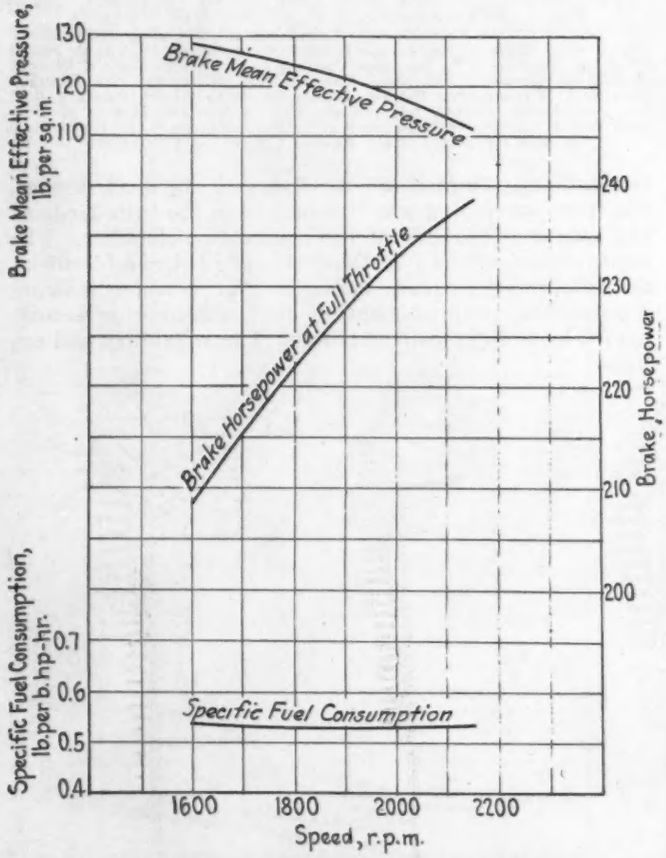

Fig. 6—Performance Curves of the J-4B Cylinder

This Cylinder Retains the Same General Lines of the J-4A Cylinder But the Fin-Area Is Greatly Increased and, To Provide Better Circulation of Air Around the Head, the Ports Are Separated, Leaving a Free Passage between Them. To Facilitate Air-Flow over the Head Further, the Front Spark-Plug Was Removed from the Cylinder-Head and Placed at the Side of the Combustion-Chamber. The Improvement Effected by These Changes Is Brought Out by the Curves Shown

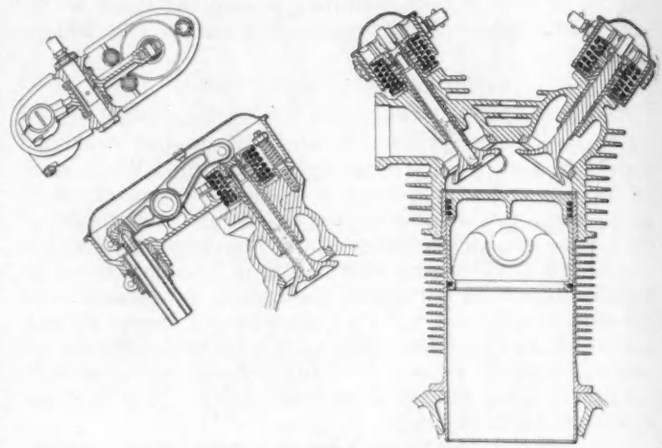

Fig. 7—Model J-5 Cylinder Construction

The Cylinder Is Characterized by a Hemispherical Combustion-Chamber, Employing Two Valves Inclined at Approximately 70 Deg. The Valve-Seats Are of Aluminum-Bronze Shrunk into the Cast-Aluminum Head. The Cylinder-Barrel with Integral Cooling-Fins and Hold-Down Flange Is Screwed and Shrunk into the Aluminum-Head Casting

The geographic distribution of these engines is also extremely interesting. Many are familiar with their flight across the North Pole, and they are giving equally good satisfaction in the tropical climates of Brazil and Peru, and in the southern portion of the United States. Several engines of this type are also employed by the Cuban Government, where they are establishing an enviable record for reliability and all-round performance. Perhaps the most severe service to which these engines have been subjected has been in connection with the Huff-Daland dusting activities, where the flying is practically confined to full-throttle operation at low altitudes over the Southern cotton fields in the warmest seasons of the year.

Further Development

While the performance of the J-4B cylinder has been highly gratifying, the best fuel consumption obtainable with this type of cylinder was still slightly inferior to the results being obtained with the better engines in the water-cooled class. To correct this condition and place the air-cooled engine fully on a par with the water-cooled type as regards fuel consumption, compression-ratio and mean effective pressure, the development of the J-5 type was undertaken. It was decided to abandon the Lawrance type of cylinder in favor of the type developed by S. D. Heron. The general type of construction employed is now thoroughly familiar to those interested in the progress of the air-cooled-engine, and it now forms the basis of the entire American air-cooled aircraft-engine development.

Fig. 7 shows the form adopted for the J-5 engine. The cylinder is characterized by a hemispherical combustion-chamber, employing two valves with axes inclined at approximately 70 deg. The valve-seats are of aluminum-bronze shrunk into the cast-aluminum head. The cylinder-barrel with integral cooling-fins and hold-down flange is screwed and shrunk into the aluminum-head casting. Cylinders of this type have been built and tested by Mr. Heron with various arrangements of intake and exhaust ports and have been uniformly successful in equalling or surpassing in fuel consumption and mean effective pressure the best results obtained by water-cooled engines. The experimental forerunner of the J-5 cylinder was the first air-cooled aircraft-cylinder

to employ a completely enclosed valve-gear. The results obtained during the single-cylinder tests of this type were discussed in a paper by S. D. Heron on Aircraft-Engine Practice as Applied to Air-Cooled Passenger-Car Engines[3] and, so far as I am aware, those results have never been surpassed by cylinders of either the air-cooled or the water-cooled type.

Advantages of the J-5 Cylinder

Among the advantages of this cylinder over the Lawrance type might be mentioned the superior head-cooling due to the larger fin-area provided by the hemispherical combustion-chamber and the relatively large space between the valve-ports; the superior barrel-cooling due to the integral steel-fins, which avoids the necessity of conducting the heat across a thermal gap between the aluminum barrel and the steel liner; the high fuel-economy presumably due to the excellent combustion-chamber shape and to the efficiency of the valve cooling; greater strength and ability to withstand abuse due to the hemispherical shape of the combustion-chamber and the superior cooling; and remarkable freedom from detonation presumably due to the combustion-chamber shape, valve cooling and spark-plug position. The shape of the combustion-chamber offers the further advantage that relatively large valves can be employed without unduly crowding the valve-seats together at the center of the head.

From a manufacturing point of view, this cylinder also possesses several advantages over the previous type. The cylinder-head casting is extremely simple, there being no loose pieces on the pattern and the core work being confined to a single one-piece core. The apparent cost of producing the barrel with integral steel-fins is more than offset by the fact that the grinding of the outside of the steel liner and the inside of the aluminum barrel, which was required in the Lawrance type of cylinder, is eliminated. The relative accessibility of the interior of the cylinder-head before the barrel is screwed into place further facilitates machining and inspection. In spite of the fact that this cylinder has now been in production only a few weeks, foundry rejections have dropped to a small fraction of the best record obtained after 4 years of experience with the Lawrance type, and the rejection of a finished cylinder due to leakage at the joint is unknown.

The Whirlwind engine, as equipped with this type of cylinder, is illustrated in Fig. 8. Aside from the changes necessary to permit mounting the new cylinder, the construction of the crankcase was not altered from that of the J-4A type. In view of the superior cooling expected from the new type of cylinder, the compression-ratio was raised from 5.20 to 5.44. The performance curves of the engine are shown in Fig. 9. The horsepower, mean-effective-pressure and full-throttle fuel-consumption curves are based on an average of the performances of the first 15 engines produced.

Cooling Efficiency and Fuel Consumption

It is interesting to note that these engines were tested during the month of July, under extremely severe conditions, the average temperature of the cooling air in the tunnel being over 90 deg. fahr. The degree of cooling efficiency obtained is indicated by the fact that, when the standard corrections for barometric pressure and carbureter-inlet temperatures are made, this curve checks exactly the power curve secured on the experimental engine during the early part of April when the temperature of the cooling air in the tunnel was approximately 40 deg. fahr. These results seem to indicate that the performance of the J-5 is fully as independent of atmos-

[3] See The Journal, January, 1923, p. 31.

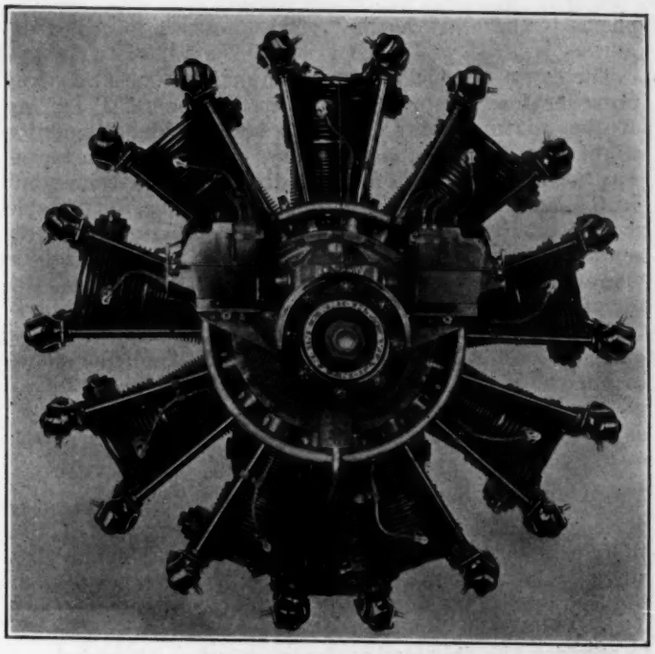

Fig. 8—Model J-5 Engine
Aside from the Changes Necessary To Permit Mounting the New J-5 Cylinder, the Construction of the Crankcase Was Not Altered from That of the J-4A Type. In View of the Superior Cooling Expected from the New Type of Cylinder, the Compression-Ratio Was Raised from 5.20 to 5.44

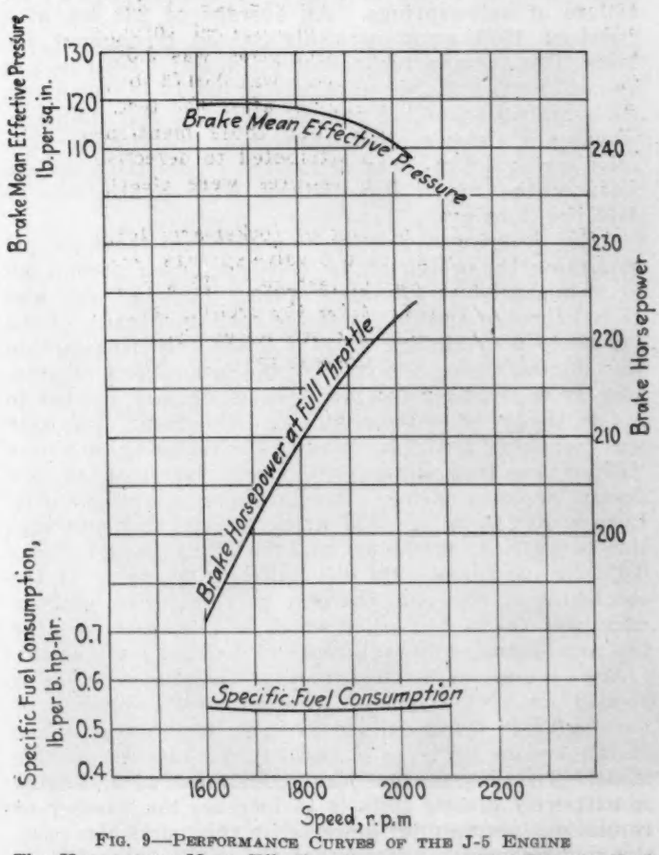

Fig. 9—Performance Curves of the J-5 Engine
The Horsepower, Mean Effective Pressure and Full-Throttle Fuel Consumption Curves Shown Are Based on an Average of the Performances of the First 15 Engines Produced

pheric temperature as that of the best water-cooled engines.

The curve for fuel consumption marked "best economy propeller load" represents the most economical setting of the mixture control, and to secure this economy a slight drop in power is necessary. This curve, however, was not made up from flash readings, but, for each point on the curve, successive readings were taken until stable conditions were obtained. The curve, therefore, represents fuel consumptions at which the engine can be operated continuously. During this particular test, the air temperature in the tunnel was 94 deg. fahr. A sustained consumption of 0.46 lb. per hp-hr., using undoped gasoline and a compression-ratio of 5.44, should serve to put the air-cooled engine definitely on a par with, if not somewhat ahead of, the best water-cooled engines, as regards fuel economy.

Endurance Tests

Due to the vast amount of successful operating experience accumulated with the previous models of the Whirlwind series and to the thorough and exhaustive single-cylinder tests of the type of cylinder employed, the first endurance test of the J-5 engine was undertaken with considerable confidence. It was, therefore, decided to abandon the standard test, consisting of 10 periods of 4½ hr. at nine-tenths of full load followed by ½ hr. at full load, and to substitute 50 hr. of full-throttle operation. To demonstrate that the J-5 was fully on a par with the water-cooled engines as regards fuel consumption, it was decided to maintain a consumption of approximately 0.50 lb. per hp-hr. throughout the test. The first 50-hr. test was completed without difficulty, except the failure of several rocker-arms and the repeated failure of valve-springs. An average of 238 hp. at a speed of 1971 r.p.m. was maintained throughout the test. The average fuel-consumption was 0.5080 lb. per hp-hr., and the oil consumption was 0.0173 lb. per hp-hr. An examination of the engine, after the test, failed to reveal any defects other than those mentioned. The valve-spring failure was attributed to defective design, whereas the rocker-arm failures were clearly due to defective forgings.

After securing a new lot of rocker-arm forgings and modifying the design of the valve-springs, a second 50-hr. endurance-test was undertaken. This test was also at full throttle and, to stress the cooling capacity of the engine to a maximum, a much lower fuel consumption was decided upon. To prevent the mean effective pressure from reaching too low a value, it was decided to reduce the speed of the engine to 1800 r.p.m. This test was completed with no difficulties whatsoever, and was entirely free from failures of rocker-arms or of the new design of valve-spring. The average operating-conditions were 216 hp. at 1827 r.p.m., with a fuel consumption of 0.458 lb. per hp-hr., and the oil consumption was 0.015 lb. per hp-hr. On dismantling the engine at the conclusion of this test, the only part requiring replacement was one rocker-roller which had stuck during the test and become sufficiently worn to warrant replacement.

The results of this test were so satisfactory that it seemed desirable to conduct an even more severe test of the engine to bring out any possible weaknesses in the design before going into quantity production on this model. The most obvious means of subjecting an engine to extremely drastic tests is to increase the number of revolutions per minute; however, in this particular case, the power curves indicated that the engine was close to its peak at 2000 r.p.m., and it appeared possible that the lower mean effective pressure accompanying the higher crankshaft-speed would tend to make the test less severe from the cooling point of view. It was, therefore, decided to equip the engine with an externally driven supercharger, so that both the speed and the mean effective pressure might be increased. After some preliminary experimentation, the engine was brought up to a speed of 2150 r.p.m., with an uncorrected power-output of 295 hp., which corresponds to a brake mean effective pressure of 138 lb. per sq. in. The engine seemed to operate satisfactorily under these conditions, in spite of the fact that the temperature of the air leaving the supercharger was approximately 140 deg. fahr. and that the fuel used was domestic aviation-gasoline. No benzol or anti-detonating compounds of any kind were used.

After a check run of 1 hr. to observe the performance of the engine, it was decided to start a 50-hr. full-throttle endurance-test under these conditions. During the first few hours of this test, there were several failures of the upper valve-spring collars, and this was at first interpreted as an inherent weakness in this member. After about 5 hr. of operation, these parts were replaced by a collar of heavier design, but the failures continued at approximately the same frequency as had been encountered with the first design. It was, therefore, concluded that the difficulty was due to the fact that the valves were not following the cam at the higher speed employed during this test and that the failure was due to the valve-springs closing-up solidly against the collar. To correct this trouble, the engine was partly dismantled after 10 hr. of running and the cam was modified so as to reduce the maximum acceleration. It is interesting to note that while the lift was not changed and the maximum amount removed from the cam at any point was only 0.012 in., this slight change in the form of the acceleration curve proved so effective that, throughout the balance of the 50-hr. test, no further failures of the valve-spring collars occurred. The remaining 40 hr. of this endurance test was run off during 5 working-days, the only failures occurring being three valve-springs, one rocker-arm and one rocker-arm adjusting-screw. The average operating conditions throughout the test were an uncorrected power-output of 295 hp. at 2150 r.p.m., with a fuel consumption of 0.510 lb. per hp-hr. An examination at the end of the test indicated that the only replacements required were three valve-rocker rollers and one valve-rocker pin. The remainder of the engine was in excellent condition and in every way suitable for continued operation.

Test Results Summarized

Summarizing these tests briefly, the engine has been subjected to 50 hr. at full-throttle operation at 2000 r.p.m., with a fuel consumption of 0.508 lb. per hp-hr.; 50 hr. at full-throttle operation at 1800 r.p.m., with a fuel consumption of 0.458 lb. per hp-hr.; and 50 hr. supercharged operation at 295 hp. and 2150 r.p.m., with a fuel consumption of 0.510 lb. per hp-hr. All this testing has been carried out with domestic aviation-gasoline. The supercharged test was conducted during August when the prevailing atmospheric temperature was at its highest and, due to the action of the supercharger, with the air entering the carbureter at a temperature of approximately 140 deg. fahr. In spite of these severe conditions, there was no evidence of detonation.

These results speak for themselves, and serve to place the air-cooled engine definitely on an equal footing with the best water-cooled engines. So far as I am aware, no other aircraft engine, whether water-cooled or air-cooled,

(*Concluded on p.* 320)

Lighting Equipment for Airways, Airports and Airplanes

AERONAUTIC MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

THE subject is treated in a paper in two parts. Part I, by H. C. Ritchie, admits the necessity for night flying, asserts that lighting equipment on the airways is a requisite and discusses the navigational aids needed to enable a pilot to keep on his course. The early stages of the development of airway-lighting devices are illustrated and reviewed, and general comment on present devices and practices is made. Part II, by C. T. Ludington, outlines certain other phases of aeronautic lighting and particularizes on the products of the company represented by the author, being accompanied also with views showing present equipment and methods.

After noting the historical features of development, Mr. Ritchie says that in general the requirements of airway lighting demand the provision of light enough on the ground to afford an aircraft pilot a distinguishable landmark. Perhaps this means that eventually small lights will be placed on the ground about 1000 ft. apart along the entire airway, but the present system uses the 24-in. incandescent 7,500,000-cp. beacon at approximately 10-mile intervals, mounted on a 53-ft. steel-tower. In addition, cluster beacons of less candlepower and consisting of four automobile head-lamps surmounted by a top lamp are used; the lamps are equipped with 21-cp. lights, the beams project horizontally, the assembly turns at 10 r.p.m., and such a beacon is visible at a distance of 40 miles in good weather.

Emergency landing-field lighting, consisting of a 24-in. beacon and 2-cp. boundary-lights spaced about 250 ft. apart around the field is described, and five specific principal requirements of airport lighting are cited. Airport beacons, boundary lights and circuits are treated, and obstruction lights, runway markers and the floodlighting of fields and hangars are dealt with briefly.

In Part II, after reviewing the early development of the products of the company he represents, Mr. Ludington discusses the large floodlights which throw out a beam having a divergence of between 1½ and 2 deg. vertically but a horizontal divergence of 180 deg. The beam is parallel to the ground, the upper surface is low and the cut-off is very sharp; so, a semicircle having a radius of ½ mile is illuminated in a satisfactory manner. With the bottom of the beam adjusted so as to be parallel with the surface of water, night landings on water are said to be as successful as those on a landing-field.

Gas and electric flashing-beacons are considered, acetylene flashers being most useful in unsettled country where electric current is not available and it is not desirable to use a generating unit. Electric flashing-beacons have certain distinct uses, although no great need for them has developed as yet. A smaller type of 180-deg. floodlight has proved useful for installation at the smaller airports and on fields having an undulating surface, and these are unexcelled as light providers for deck landings on shipboard.

Two units have been developed recently. The B. B. T. 180-deg. type uses a cut-glass Fresnel lens about 7 in. high and of 7-in. diameter, and is equipped with a spherical mirror supplemented by two 180-deg. circular parabolic-mirrors above and below the lens. The light-source consists of a 1000-watt ordinary Mazda-lamp, a 1000-watt stereopticon lamp or a 900-watt 30-volt lamp, according to the specific purpose to be served. The other type, a General Electric Co. unit, is similar but uses an 8-in. 120-deg. Fresnel lens and a spherical mirror; it has no parabolic reflectors and is somewhat differently housed, but is similarly mounted.

Airplane lighting is described, the types and locations of the lights on the machine being stated. Neon gas in tubes through which an electric current is passed provides a cold red light having great power to penetrate mist and fog, and Neon lights should be useful for night flying. The lighting equipment of the airway from Chicago to Dallas, Tex., is specified, and conclusions are drawn relative to the probable future of airway lighting means and methods.

PART I BY H. C. RITCHIE[1]

MEMBERS of the Society of Automotive Engineers who are interested in aeronautics realize the necessity for night flying. The great advantage to be gained is in the utilization of time which ordinarily is not used for business, but night flying also

FIG. 1—45-DEG. MIRROR AND OSCILLATING DEVICE
A Searchlight Beam Was Directed Horizontally Against a Plane Mirror Placed at an Angle of 45 Deg. in Front of the Searchlight. The Mirror Was Oscillated by a Motor So That the Beam Described a Circle on the Clouds. With Good Visibility, This Was Seen at a Distance of 140 Miles

[1] Aviation lighting specialist, General Electric Co., Schenectady, N. Y.

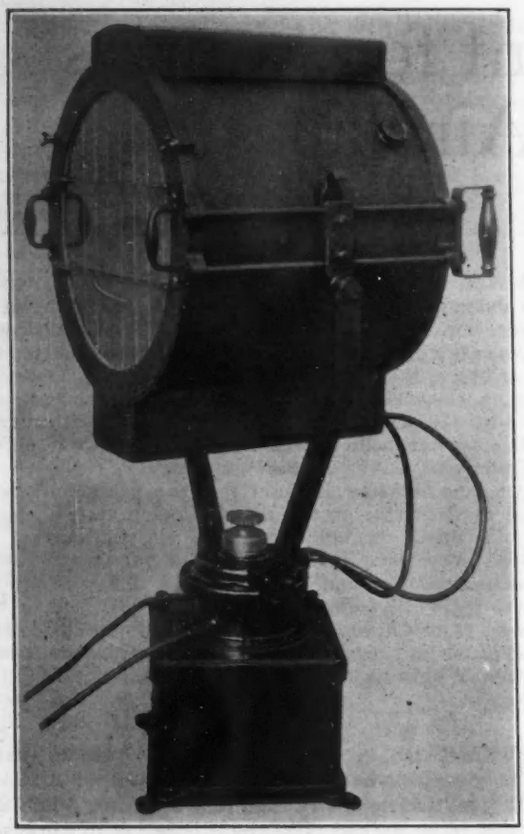

FIG. 2—18-IN. GENERAL ELECTRIC CO. BEACON
The First Lighted Section of the Night Airway from Chicago to Cheyenne, Wyo., Was Lighted at 25-Mile Intervals with 18-In. Revolving-Searchlights of the Type Shown, Using a 900-Watt 30-Volt Mazda-Lamp

makes possible universal and continued air transportation. There would be no advantage in rushing packages, mail or freight at 100 m.p.h. or more during daylight, and then waiting on the ground until daylight appeared again.

Admitting the necessity for night flying, what navigational aids are needed to enable a pilot to keep on his course with the least possible effort on his part and at the same time to do this in an economical manner? Perhaps the answer lies with the magnetic or radio compass or with radio directional beacons, but the success of the United States Air Mail Service in its night operations warrants the assertion that lighting equipment on the airways is an absolute necessity.

AIRWAY-LIGHTING DEVELOPMENT

Pictures of the early development of airway-lighting devices are interesting in that they show how and why the present equipment came to be adopted. Probably the most notable beacon is the large one at Dijon, France, which is described in Part II of this paper. Another early beacon was that installed by the British Air Ministry at Croydon, England.

Some years ago the Army Air Service and the Bureau of Lighthouses conducted experiments on a searchlight beam of very high candlepower directed toward the zenith. In this case the eye did not receive direct light from the searchlight, but the light was reflected from the moisture and dust particles in the air. Another experiment along this line was in directing the searchlight beam horizontally against a plane mirror placed at an angle of 45 deg. in front of the searchlight, as shown in Fig. 1. The 45-deg. mirror was oscillated by a motor so that the beam described a circle on the clouds. With good visibility, this was seen at a distance of 140 miles.

Although the engineers of the Post Office Department were familiar with these experiments, they decided that the expense of high-powered searchlights would be prohibitive in the regular operation of a night airway and decided on the use of smaller units located at shorter intervals, these revolving searchlights to use incandescent lamps so as to do away with the necessity for skilled operators. The first section lighted from Chicago to Cheyenne, Wyo., was marked at 25-mile intervals with 18-in. revolving searchlights of the type shown in Fig. 2, using the 900-watt 30-volt Mazda lamp. As an added factor of safety the operating fields at Maywood, Ill., Iowa City, Iowa; Omaha and North Platte, Neb.; and Cheyenne, Wyo., were equipped also with 36-in. high-intensity revolving searchlights such as that shown in Fig. 3.

The 18-in. beacon was found too small and was later superseded by the 24-in. revolving beacon shown in Fig. 4, which, equipped with the 900-watt lamp, has a beam-intensity of 7,500,000 cp. This size of beacon is now the American airway standard. Similarly, a number of experiments were made and are still being conducted on the lighting of landing-fields. Small floodlights such as

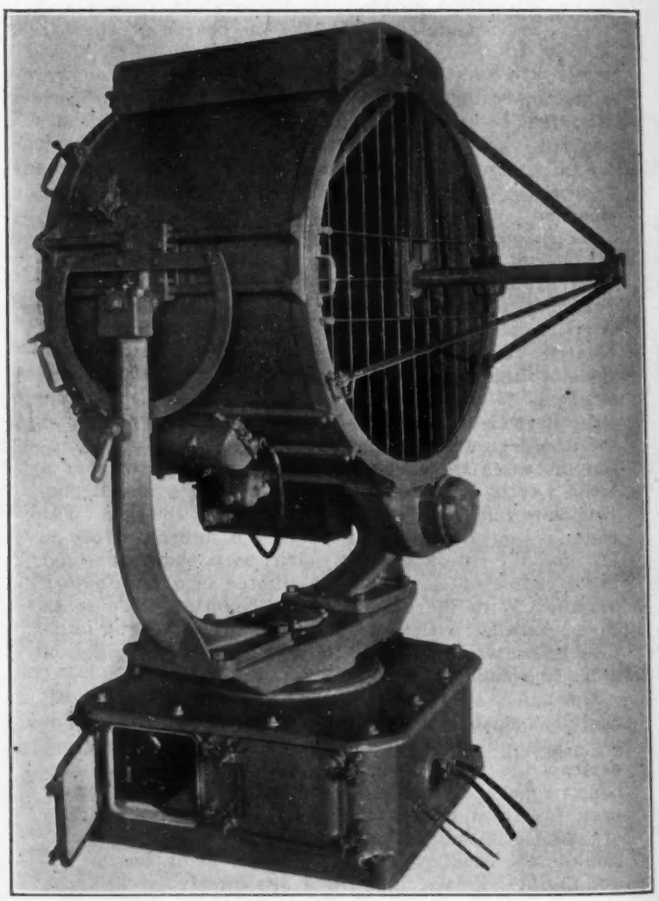

FIG. 3—36-IN. GENERAL ELECTRIC CO. HIGH-INTENSITY BEACON
In Addition to the Beacons of the Type Shown in Fig. 2, Used to Light the Night Airway from Chicago to Cheyenne, Wyo., Various Operating Fields along the Route Were Equipped Also with 36-In. High-Intensity Revolving-Searchlights Such as That Shown

FIG. 4—24-IN. GENERAL ELECTRIC CO. BEACON
Since the 18-In. Beacon Was Found To Be too Small, It Was Superseded by the 24-In. Revolving-Beacon Shown, Which, Equipped with a 900-Watt Lamp, Has a Beam Intensity of 7,500,000 Cp. This Size of Beacon Is Now the American Airway Standard

shown in Fig. 5 were employed in the attempt to distribute light on the ground.

With the development of a high-intensity arc, experiments with high-powered searchlights for field illumination were made between 1915 and 1920. These usually were portable units, sometimes being mounted on motor-trucks as in Fig. 6 so that they could be moved around the field when the direction of the wind changed. The addition of searchlight-doors that cause the light-rays to diverge gave a wide-angle beam as indicated in Fig. 7, and illuminated a much larger area, but at a lower intensity. The next marked improvement was the adaptation of large Fresnel lenses to field lighting (See Fig. 8) and later made feasible the substitution of small units for the more expensive large units. In practice not only was the field marked by a beacon and the ground floodlighted but the boundaries of the field were outlined, obstructions were marked with red lights and the roofs and elevations of buildings were floodlighted to give perspective.

AIRWAY-LIGHTING EQUIPMENT

In general, the requirements of airway lighting are that there be provided some light on the ground that will give a pilot a distinguishable landmark. Perhaps this means that eventually small lights will be placed on the ground about 1000 ft. apart along the entire airway. However, the present system uses the 24-in. incandescent 7,500,000-cp. beacon at approximately 10-mile intervals. The beacons are mounted on 53-ft. steel towers similar to commercial windmill towers. These are about 12 ft. square at the base. A small shack usually is built into this base to house the switches for the beacon and to act as a shelter for the caretaker. In cases where local electric-power is not available, a 1250 or a 1500-watt gasoline-engine driven generating-set also is installed in this shack.

Fig. 9 shows not only the 24-in. beacon on its steel tower but a wind-driven electric generating-set on an additional tower. This practice has been found satisfactory in localities in which the wind is fairly constant. The generator is driven by a wind-driven propeller and charges a 32-volt storage-battery which provides power when there is not sufficient wind to operate the generating set. Automatic regulation of the speed of the generator is provided by mechanical rather than by electrical means.

THE 24-IN. BEACON

The 24-in. beacon has a stationary base which contains a motor, worm-gearing and a slip-ring. The base supports the top and the bottom ball-bearings of the revolving shaft. The top of the shaft carries a turntable to which are attached the arms supporting the barrel. The motor is connected through a worm-gear and a slip-clutch to the center shaft. The slip-clutch is provided so that the searchlight can be turned by hand in any direction without stopping the driving motor, and so that there will be no damage to the gearing in case the searchlight barrel is stopped accidentally. The barrel revolves at a speed of approximately 6 r.p.m., which gives a 10-sec. flash. A high-grade silvered-glass parabolic-mirror is used with this beacon, this being protected by a sheet-metal dome attached to the rear of the barrel. The front door is of ¼-in. plate-glass mounted in a metal ring which is hinged to give easy access to the lamp. This door is held rigidly in place by four ring-and-lever clamps.

CLUSTER BEACONS

In addition to the 24-in. beacons it was found advisable in certain sections of the Eastern Division to place cluster beacons having less candlepower. They consist

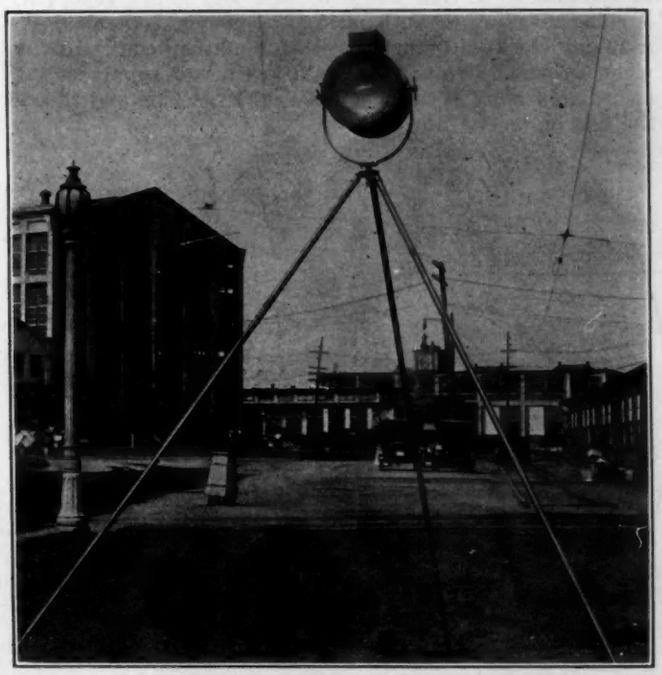

FIG. 5—EARLY INCANDESCENT FLOODLIGHT
Small Floodlights Such as This Were Employed in the Attempt to Distribute Light on the Ground

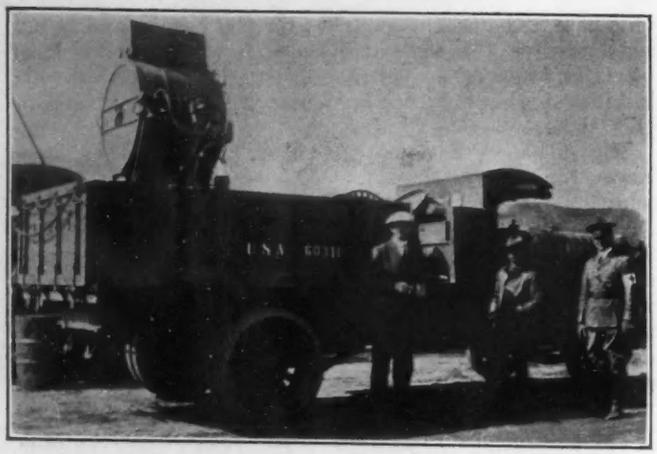

FIG. 6—36-IN. SEARCHLIGHT MOUNTED ON A MOTOR-TRUCK
Portable Units Having High Power for Field Illumination Were Sometimes Mounted on Motor-Trucks So That They Could Be Moved Around the Field When the Direction of the Wind Changed, Thus Preventing Glare in the Eyes of an Incoming Pilot

of four automobile head-lamps surmounted by a top lamp as shown in Fig. 10, and turn at approximately 10 r.p.m. The beams from the automobile head-lamps project in a practically horizontal direction. Tests of such a beacon, using 21-cp. automobile-type lamps, show that it is visible at a distance of 40 miles in good weather.

A map of a portion of the Eastern Division of the Air Mail Service is shown in Fig. 11. The section shown is approximately 65 miles long and is from Cortland, Ohio, to Lamartine, Pa. Seven 24-in. beacons are shown in this section as well as five emergency landing-fields. At present it is necessary to have a caretaker stationed at each beacon to change lamps in case of burnouts; however, with the recent development of an automatic lamp-changer, these caretakers can be dispensed with and the maintenance and operating expenses can thereby be greatly reduced. When the reserve lamp is put into use by the lamp changer, a red light is shown from the top of the beacon so that the pilot who sees it can report it. A sun-valve or an automatic time-switch controlled by a 40-day clock will start the beacon at the required hour when operated from central-station power-supply or, if an isolated plant is used, will start the engine and throw the beacon on the line.

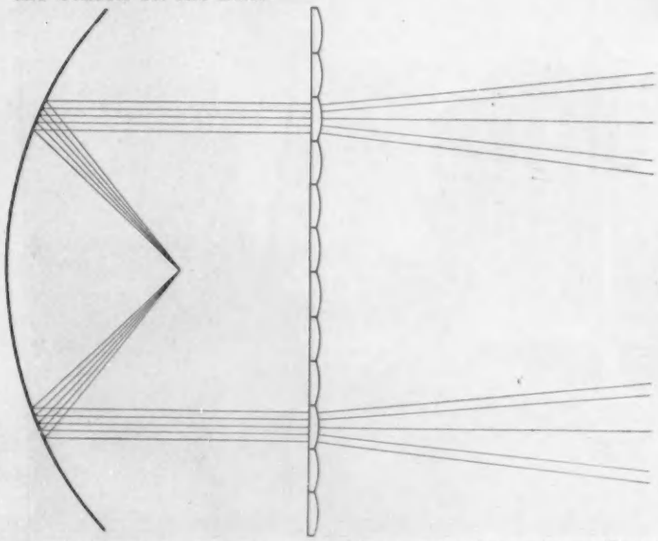

FIG. 7—EFFECT OF DIVERGING DOOR-GLASS ON A SEARCHLIGHT BEAM
The Addition of Searchlight-Doors That Cause the Light-Rays To Diverge As Shown Gave a Wide-Angle Beam and Illuminated a Much Larger Area but at a Lower Intensity

When the need for a telephone and telegraph service between all stations on the airway is considered, it seems advisable on future layouts of airways to consider a pole line for the entire length with power available at all points. A liberal estimate of the cost of such a pole line without lighting fixtures is about $1,250 per mile.

EMERGENCY LANDING-FIELD LIGHTING

The lighting of emergency landing-fields as part of the airway should be considered as distinguished from lighting an airport or terminal field. It has been the practice for the Air Mail Service to station the 24-in. beacons at emergency landing-fields. The field lighting has consisted of a 24-in. beacon and, in addition, 2-cp. boundary-lights placed about 250 ft. apart around the field. As in most cases no local electric-power is available, no attempt was made to floodlight the field, the headlights

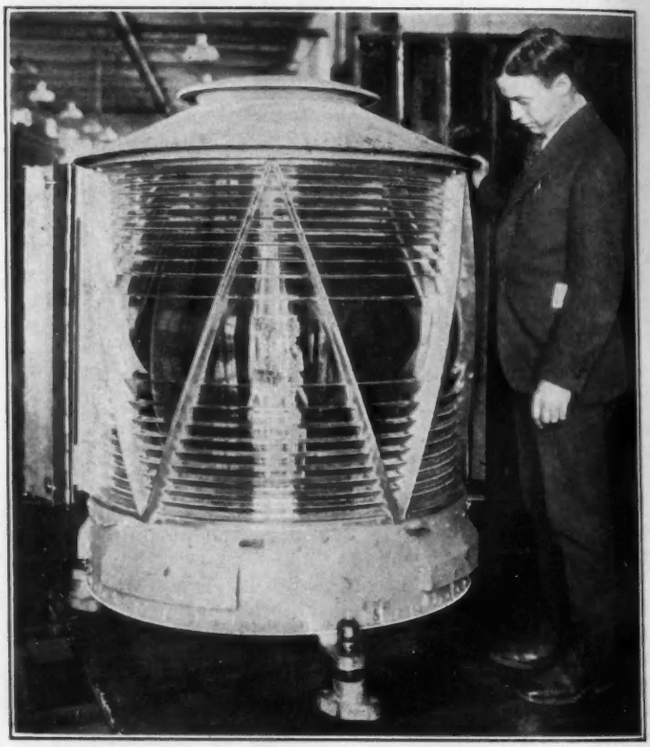

FIG. 8—LARGE B. B. T. CORPORATION FLOODLIGHT WITH FRESNEL LENS
The Adaptation of Large Fresnel Lenses to Field Lighting Was a Marked Improvement and Later Made Possible the Substitution of Small Units for the More Expensive Large Units

on the airplane or parachute flares being considered ample for emergency landing. However, with the increase of traffic which is expected within the next 2 or 3 years, it can reasonably be expected that a great number of emergency landing-fields will be lighted in the same manner that the airports are now lighted, but with a smaller number of units or units of a smaller size.

AIRPORT LIGHTING

The principal requirements of a well-lighted airport are as follows:

(1) A beacon which will indicate from a distance the location of the field
(2) Boundary markers to outline the limits of the field, which lights shall be visible when the pilot is approaching
(3) Red obstruction-lights must be placed on buildings, power lines or water towers that are close

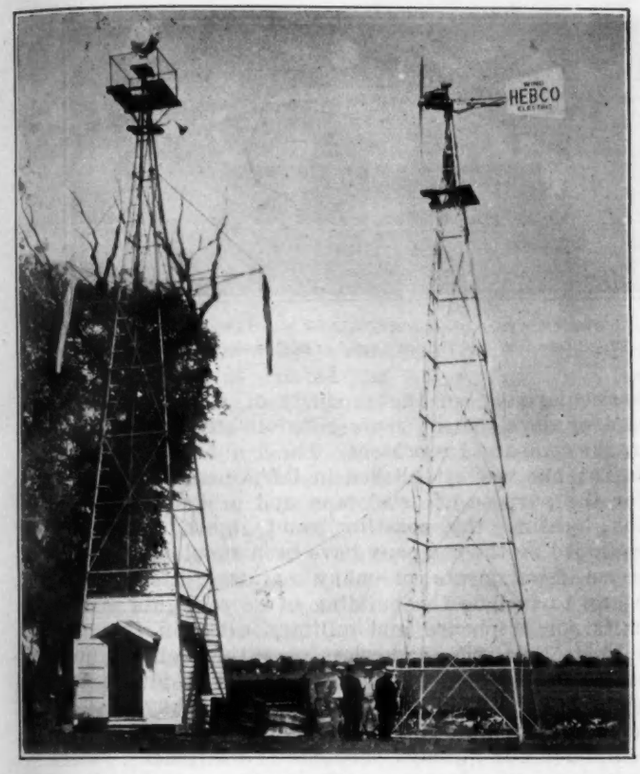

FIG. 9—24-IN. BEACON AND WIND-DRIVEN ELECTRIC GENERATING-SET

The Present System of Airway Lighting Uses the 24-In. Incandescent 7,500,000-Cp. Beacon at Approximately 10-Mile Intervals. The Beacons Are Mounted on 53-Ft. Steel-Towers, These Being about 12 Ft. Square at the Base. A Small Shack Usually Is Built Into This Base To House the Switches for the Beacon and To Act as a Shelter for the Caretaker. In Cases Where Local Electric-Power Is Not Available, a 1250 or a 1500-Watt Gasoline-Engine Driven Generating-Set Is Also Installed in the Shack. In Localities in Which the Wind Is Fairly Constant, a Wind-Driven Electric Generating-Set Is Mounted on a Supplementary Tower As Shown and This Practice Has Been Found Satisfactory. The Generator Is Driven by a Wind-Driven Propeller and Charges a 32-Volt Storage-Battery Which Provides Power when There Is Not Sufficient Wind To Operate the Generator

enough to the field to be an obstruction to landing or taking-off

(4) Sufficient light must be distributed on the ground to make possible perfectly safe landing on the field

(5) Hangars and other buildings should be floodlighted to give the approaching pilot some means to gage his height above ground and his distance from the field

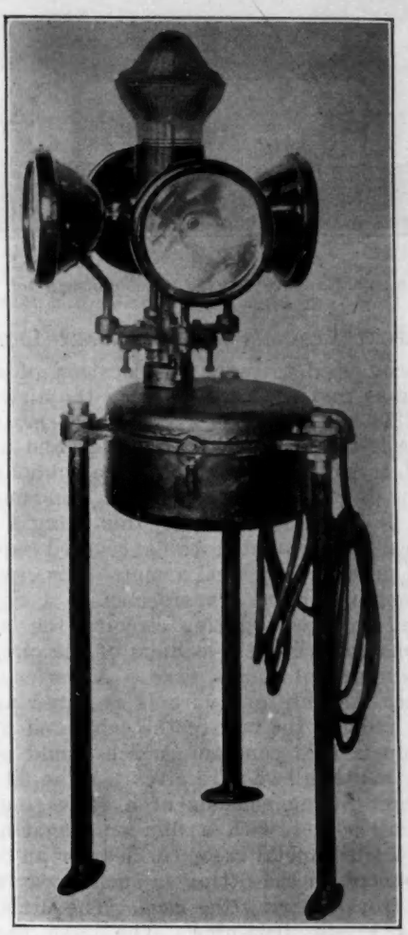

FIG. 10—GENERAL ELECTRIC CO. CLUSTER BEACON

In Addition to the 24-In. Beacons, It Was Found Advisable in Certain Sections To Place Cluster Beacons Having Less Candlepower. They Consist of Four Automobile Head-Lamps Surmounted by a Top Lamp As Shown, and Turn at Approximately 10 R. P. M. Tests of Such a Beacon, Using 21-Cp. Automobile-Type Lamps, Show That It Is Visible at a Distance of 40 Miles in Good Weather

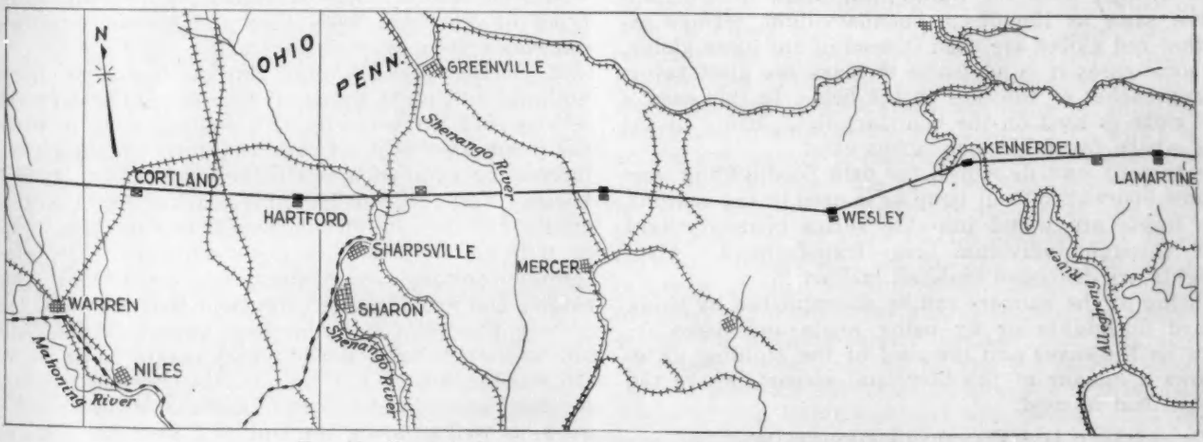

FIG. 11—EASTERN DIVISION OF THE AIR-MAIL-SERVICE AIRWAY

The Section Shown Is Approximately 65 Miles Long. Seven 24-In. Beacons and Five Emergency Landing-Fields Are Indicated. At present, It Is Necessary To Employ a Caretaker at Each Beacon To Change Lamps in Case of Burnouts; But the Recent Development of an Automatic Lamp-Changer, Which Shows a Red Light and Thus Gives Notice That the Beacon Needs Attention, Makes Possible the Elimination of Caretakers. A Sun-Valve or an Automatic Time-Switch Controlled by a 40-Day Clock Starts the Beacon at the Required Hour

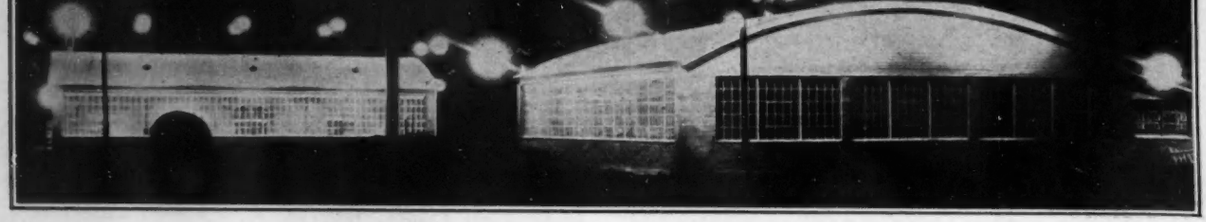

FIG. 12—HANGAR ILLUMINATION AT THE CLEVELAND AIRPORT
Lighting of Hangars Can Be Accomplished by Using Standard Floodlights or by Using Angle and Dome Reflectors on the Eaves and the Roof of the Building

AIRPORT BEACONS AND BOUNDARY LIGHTS

The beacon used to mark the location of an airport is the same as that used for marking the airway.

Where 2300-volt power is available the most economical practice is to run a series circuit around the borders of the field, to which are connected the boundary and the obstruction lights. This circuit is run underground with No. 8 B & S parkway-cable, this being a rubber or varnished-cambric-insulated cable covered with a lead sheath and protected by steel armor. This circuit is fed from a constant-current transformer of a type similar to that used on street-lighting circuits, the current being held constant while the voltage of the circuit varies with the number of lamps used. A series circuit is recommended, as only one wire is required around the field. This reduces the cost of the cable and the voltage at each lamp is held constant, which would not be the case with a multiple two-wire circuit. The 60-cp. series boundary-light fitting consists of a series incandescent street-lighting socket with a film or magazine cut-out enclosed in a sheet-metal case. A clear or an opal glass-globe is mounted on the fitting in such a way as to prevent water from entering the case. The fitting is supported on a 1¼-in. iron-pipe. The lamp used is the 600-lumen, 60-cp. series street-lighting lamp. It has been found that this gives sufficient illumination for boundary markings when the lights are placed approximately 200 ft. apart. These boundary fittings are mounted only about 3 ft. above the ground.

CONSTRUCTION LIGHTS, RUNWAY MARKERS AND FLOODLIGHTING

The fittings used for lights that mark obstructions are the same as the 60-cp. boundary-light fittings except that red globes are used instead of the clear globes.

In some cases it is advisable to mark the most favorable approaches or runways to the field. In this case, a green globe is used on the boundary-light fitting at the points where favorable approaches exist.

One type of unit developed for field floodlighting uses the same 900-watt 30-volt lamp as is used in the beacons. These lights are wired into the series boundary-light circuit through individual lamp transformers. Field floodlights are discussed in detail in Part II.

Lighting of the hangars can be accomplished by using standard floodlights or by using angle and dome reflectors on the eaves and the roof of the building. Fig. 12 shows a hangar at the Cleveland airport, where the latter method is used.

PART II BY C. T. LUDINGTON[2]

Certain phases of aeronautic lighting other than those already treated are outlined in this part of the paper, particularizing on the products of a slightly different line of development represented by the units produced by the company I represent. The firm of Barbier, Benard & Turenne was established in Paris nearly 90 years ago for the purpose of developing and producing equipment for lighting the coastline, and lighthouses built or equipped by the company have been supplied to the lighthouse departments of many nations. Its work soon began to include the building of searchlights and other units for shipboard and military uses; in the medical field its Scialytic shadowless operating-light is now almost standard equipment in first-class hospitals. Stimulated by the War, the subject of night flying led the company into extensive experiments relating to lighting equipment for airways, airports and airplanes.

Perhaps the most interesting of the company's early lights is the great 1,000,000,000-cp. beacon, 45 ft. high, located on a mountain top near Dijon, France, and known as the Dijon Light. This is reported to have a range of visibility, from a sufficient height, of up to 300 miles in clear weather. It serves to guide aircraft en route to Paris from Eastern Europe. The light-sources consist of eight automatic electric arcs and four spare burners, each fitted behind one of eight large Fresnel lenses, in two groups of four, each group being mounted on a revolving platform. The lenses are of a patented design and show light to the zenith.

The fact that the company approached the problem from the angle of marine lighting has proved to have been wise in some ways, although it is different from the method of approach used here, which, it seems to some of us, has neglected certain fundamental principles that would be useful; for example, the present standard types of floodlight, both here and abroad, are directly descended from lighthouse practice.

A feeling prevails that Europe has done little or nothing with night flying; it has no regular night-flying service, but extensive lighting-equipment is in place on the great European airways and experiments leading to interesting conclusions have been constantly carried on. Hence, in addition to handling marine lights and other products of the foreign company, it was felt that it would be well for the new American company to handle the foreign company's night-flying equipment and later to modify and manufacture equipment that took due regard of both European and American improvements. American or French B. B. T. equipment is now to be found on the Paris-London (Air Union), the Paris-Brussels-Amsterdam and the Paris-Prague-Warsaw-Bucharest airways, as well as along the United States Air Mail route and that of National Air Transport.

LARGE 180-DEG. FLOODLIGHTS

The earliest floodlighting of aviation fields was by means of gasoline or kerosene fires. Later, ordinary

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searchlights were used, these being moved around the field when the direction of the wind changed so as not to blind incoming pilots by glare. A great improvement was the use of spread lenses on ordinary searchlights, these giving a horizontal divergence of 40 deg., but none of these methods gave a uniform illumination over the field. A common error made in those days, and even now, was to place the searchlight at an altitude and shining down upon the field at a considerable angle. Most of the early methods caused considerable glare in the eyes of a pilot if he landed across or toward the beam and threw serious shadows ahead of him if he landed over it. It was obvious that, given a reasonably level field, what was wanted was a beam covering the entire area, with a small vertical divergence and a very sharp cut-off at the top, this being parallel to the surface of the field and so close to it that, in landing toward the light the eyes of the pilot would not come into the direct rays until the wheels were nearly on the ground and, in landing over it, the wings would not commence to throw shadows until a landing had been virtually effected. Under theoretically ideal conditions with average aircraft both of these contingencies can be avoided and, under normal operating-conditions, they can be minimized. The B. B. T. 180-deg. floodlight shown in Fig. 13 covers these requirements. The front half of a drum-like housing is composed of a 180-deg. Fresnel lens about 3 ft. high and 3 ft. in diameter.

As the photograph reproduced in Fig. 14 shows, this light throws out a beam with a vertical divergence of but 1½ to 2 deg. and has a horizontal divergence of 180 deg. The beam is parallel to the ground, the upper surface is low and the cut-off is very sharp. A semicircle with a radius of ½ mile is illuminated in a satisfactory manner. Besides its advantages of having a fixed location, and its elimination of glare and shadows to a large degree, the intense glow it produces is of assistance to pilots in locating the field in a mist or a fog and the spectacular quality of the illumination cannot fail to assist in the arousing of public interest in night flying.

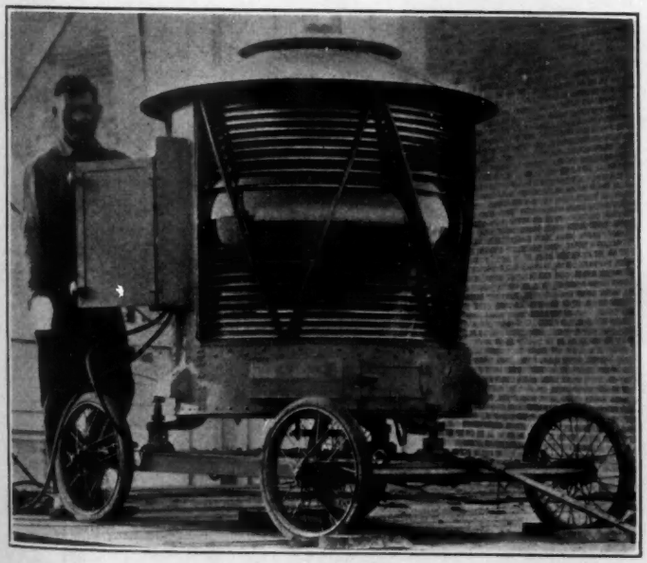


FIG. 13—LARGE 180-DEG. B. B. T. FLOODLIGHT
The Front Half of a Drum-Like Housing Is Composed of a 180-Deg. Fresnel Lens about 3 Ft. High and 3 Ft. in Diameter. The Beam Has a Vertical Divergence of 1½ to 2 Deg. but a Horizontal Divergence of 180 Deg.; It Is Parallel to the Ground, the Upper Surface Is Low and the Cut-Off Is Very Sharp. A Semicircle Having a Radius of ½ Mile Is Illuminated in a Satisfactory Manner

FLOODLIGHTING AREAS OF WATER

The problem of floodlighting areas of water for night landings had never been solved satisfactorily until the advent of this type of floodlight. Any type of light that throws its beam down upon water from a height produces a glare on the surface that is very trying to the eyes of pilots. Last year's most satisfactory tests of these lights by the Navy proved that, with the bottom of the beam adjusted so as to be parallel with the surface of the water as shown in Fig. 15, night landings on water are as simple a problem as if made on land. These lights are in use at Croydon, at Le Bourget and at several other European commercial and military fields, as well as at the principal Air Mail fields between New York City and San Francisco. The light which is later to be set up on the Philadelphia Municipal Field is at this time in use on the 1926 Air Race Field. The United States Navy also uses these floodlights.

A General Electric Co. or a Sperry 150-amp.-arc mechanism is used, or a General Electric Co. 10-kw. Mazda-lamp or similar European lamps can be used. It has never been my privilege to see one of these units in operation with a 10-kw. lamp. I have, however, seen them used with a 4-kw. lamp of foreign manufacture. A less intense, softer light, with a more natural color was produced. There was of course greater vertical divergence due to the greater size of the light-source but, in spite of this, it is my belief that further experiments with incandescent lamps will result in their being preferred by many pilots. The need for a skilled operator is eliminated, and the possibilities of using an automatic lamp-changer in case of failure at a critical instant are attractive.

GAS AND ELECTRIC FLASHING-BEACONS

As intermediate light-sources, small acetylene-gas flashing-beacons are most useful. They can be used in unsettled country where electric current is not available and where it is not desirable to use a generating set. When equipped with sun-valves as shown in Fig. 16, they will operate for 6 months without attention. A quick flash, attracting instant attention, can be secured. Such flashing beacons, made by the American Gas Accumulator Co., were installed every 3 miles on the transcontinental Air Mail route. They were visible for 3 miles or more. They use a 360-deg. Fresnel lens of pressed glass. The flashing mechanism is similar to that used in buoys and in highway flashing-beacons. The company has recently brought out an improvement in the 300-mm. (11.81-in.) pressed-glass lenses used on their flashers, which causes the light to shine to the zenith and eliminates the usual blind area which occurs as one approaches a beacon at a considerable altitude. They have increased the range of visibility to 7 miles or more. A number of these are in use by the Air Mail Service and on the route of the National Air Transport between Chicago and Dallas, Tex. This company also makes a smaller reflector-globe beacon for use as an auxiliary runway-marker and as a boundary marker for emergency landing-fields. Besides this company, the Interflash Signal Corporation and the B. B. T. Corporation of America also manufacture gas flashing-beacons. Those of the latter company are usually of a greater size and are very popular in Europe. Those of the Interflash Corporation are made in two sizes, 200 mm. (7.87 in.) and 375 mm. (14.76 in.), respectively, with an interesting combination of lens sections and a reflector to show light to the zenith.

At first, gas beacons were placed at regular intervals

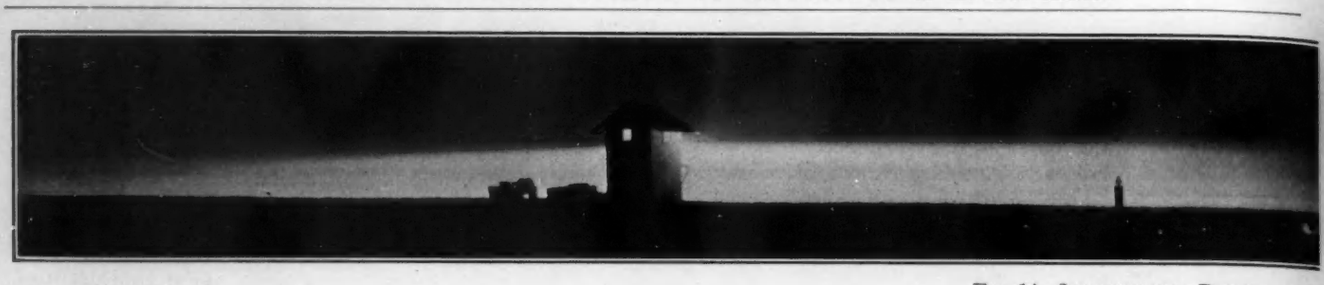


FIG. 14—ILLUMINATION PROVIDED BY
Besides Its Advantages of Having a Fixed Location and Its Elimination of Glare and Shadows to in a Mist or a Fog and the Spectacular Quality of the

regardless of terrain; but it seems to be better practice, as has recently been done in many cases, to locate them always in the same geographical corner of fields suitable for emergency landings. I recommend going even further, dividing these fields into two different classes according to quality and giving the beacons distinctive coloring or characteristics.

Electric flashing-beacons with 360-deg. lenses, such as shown in Fig. 17 have certain distinct uses. As yet, no great need for them has developed in America, as most of our night flying has been along airways well known by the pilots who use them and they are not crossed by other airways. But as developments continue and airways branch out in many directions from each large city and, later, when each large city is equipped with one or more airports, the need will be felt for the special combinations of flashes for certain routes or airports, so easily accomplished by the use of these lights, and they will replace many existing revolving-searchlight beacons. Imagine the difficulty of navigating a boat on Long Island Sound if all lights had the same characteristics!

Other advantages are the fact that they have little or no blind area and that they can give a much more frequent flash than that of an ordinary rotating-searchlight without making the flash too short in duration; therefore, they are somewhat easier to pick-up under certain conditions. This type of beacon is much preferred in Europe where revolving searchlights have largely disappeared. The reason they have not grown popular here is that, except in very large and expensive units, they have not the range of visibility of revolving searchlights and, in the smaller sizes, they require a more expensive installation than the gas flashing-beacons. I believe that forward-looking airport-promoters will do well to keep this type in mind or to consider seriously some type of beacon giving a signal easily distinguishable from the standard revolving-searchlights used along the routes. Two beacons of this type are in use near Philadelphia and have proved reliable and satisfactory.

SMALL FLOODLIGHTS

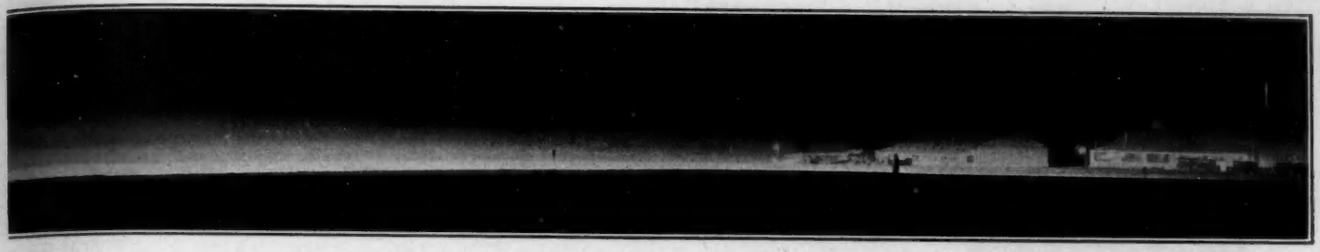
Many fields have an undulating surface and are consequently unsuitable for the installation of large 180-deg. floodlights; also, these large units are relatively expensive to purchase and to operate. For this reason the American B. B. T. Corporation began experiments some time ago with a smaller type of 180-deg. floodlight, long known abroad but, to my knowledge, not previously adapted for aviation lighting. These have been used with success in Europe for the lighting of railroad yards, parks, large advertisements, and construction operations. On account of their simplicity and relatively low cost they have proved useful for installation at smaller airports and on undulating surfaces, and are unexcelled for deck landings on shipboard.

RECENT NEW UNITS

Since the introduction of the B. B. T. units, two others have appeared and I will describe them in the order of their appearance. The B. B. T. 180-deg. type shown in Fig. 18 uses a cut-glass Fresnel lens about 7 in. high and of 7-in. diameter having a spherical mirror, supplemented by two 180-deg. circular parabolic-mirrors above and below the lens which add somewhat to the efficiency by utilizing some light from the source that otherwise would be wasted. The light-source consists of a 1000-watt ordinary Mazda-lamp, a 1000-watt stereopticon-lamp or a 900-watt 30-volt lamp, depending on the exact purpose for which the unit is to be used. This unit is also produced with a 90-deg. horizontal-divergence. Both are mounted with suitable adjusting mechanism on metal-pipe standards.

The General Electric Co. unit is similar but uses an 8-in. 120-deg. Fresnel lens of pressed glass and a spherical mirror; it has no parabolic reflectors and is some-

FIG. 15—FLOODLIGHT OF THE TYPE SHOWN IN FIG. 13 ILLUMINATING AN EXPANSE OF WATER
Any Type of Light That Throws Its Beam Down upon the Surface of Water from a Height Produces a Glare That Is Very Trying to the Eyes of Pilots. With the Bottom of the Floodlight's Beam Adjusted So As To Be Parallel with the Surface of the Water, Night Landings on Water Are as Simple a Problem As If Made on Land



THE FLOODLIGHT SHOWN IN FIG. 13
a Large Degree, the Intense Glow It Produces Is of Assistance to Pilots in Locating the Field Illumination Assists in Arousing Public Interest in Night Flying

what differently housed but is similarly mounted. It is understood that the Sperry Gyroscope Co. has produced a similar unit recently, but at this time no details are at hand.

As will be seen from the photograph taken by the light from a B. B. T. unit located at second base of the baseball diamond in Shibe Park, Philadelphia, shown in Fig. 19, the illumination from the smaller Fresnel floodlights is similar to that of the large B. B. T. lights except that it is far less intense and, of necessity, the vertical divergence is greater. With the B. B. T. light the useful radius of the semi-circle is between 500 and 750 ft., depending on the terrain and the adjustment of the focus. With but one of these units in use, I have been able to read telegrams at a distance of 1800 ft. from the light.

Fig. 20 shows a battery of four of the small floodlights mounted on a light hand-truck. This scheme is valuable for temporary use on large fields where night landings are infrequent. For permanent use, from two to four lights located at right angles on two sides of the field are recommended.

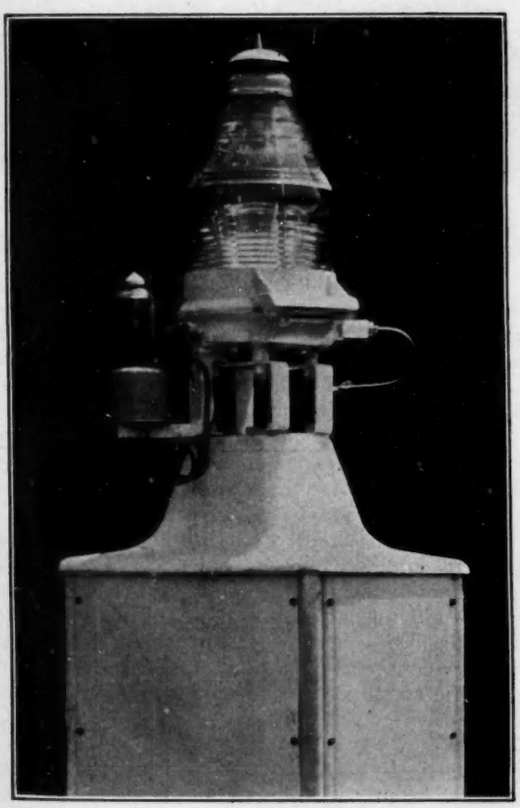


FIG. 16—AMERICAN GAS ACCUMULATOR CO. GAS FLASHING-BEACON EQUIPPED WITH A SUN-VALVE
As Intermediate Light-Sources, Small Acetylene-Gas Flashing-Beacons Are Useful. They Can Be Used in Unsettled Sections Where Electric Current Is Not Available and Where It Is Not Desirable To Use a Generating-Set. When Equipped with a Sun-Valve As Shown, They Will Operate for 6 Months without Attention. A Quick Flash, Attracting Instant Attention, Can Be Secured

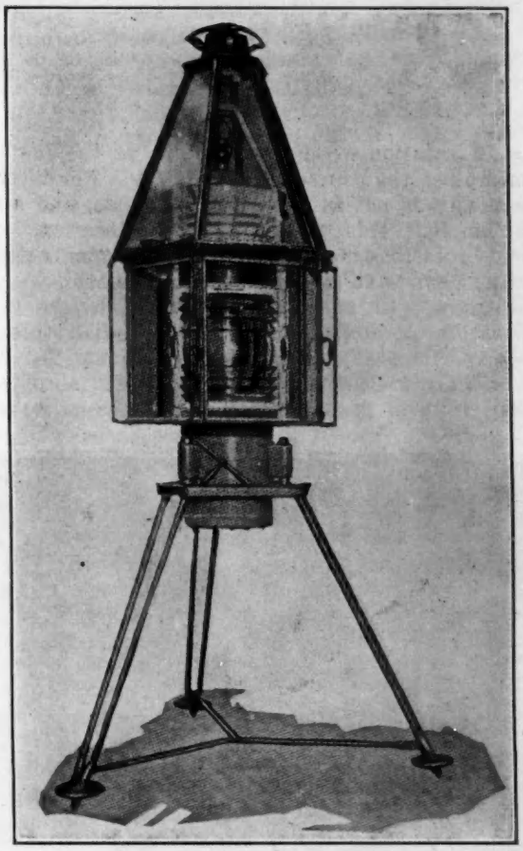


FIG. 17—ELECTRIC FLASHING-BEACON
Such Beacons, Equipped with 360-Deg. Lenses, Have Certain Distinct Uses. As Yet, No Great Need for Them Has Developed in America; But, as Developments Continue and Airways Branch Out in Many Directions from Each Large City and, Later, When Each Large City Is Equipped with One or More Airports, the Need Will Be Felt for the Special Combinations of Flashes for Certain Routes or Airports, So Easily Accomplished by the Use of These Lights, and They Will Replace Many Existing Revolving-Searchlight Beacons

WABBLER MECHANISM OF THE B. B. T. UNIT

One disadvantage of the usual rotating-searchlight is that it cannot be revolved rapidly for the desired large number of flashes per minute without reducing the duration of the flash seriously, especially to an observer located at a considerable distance. Consequently, it seems desirable to slow down or momentarily check the

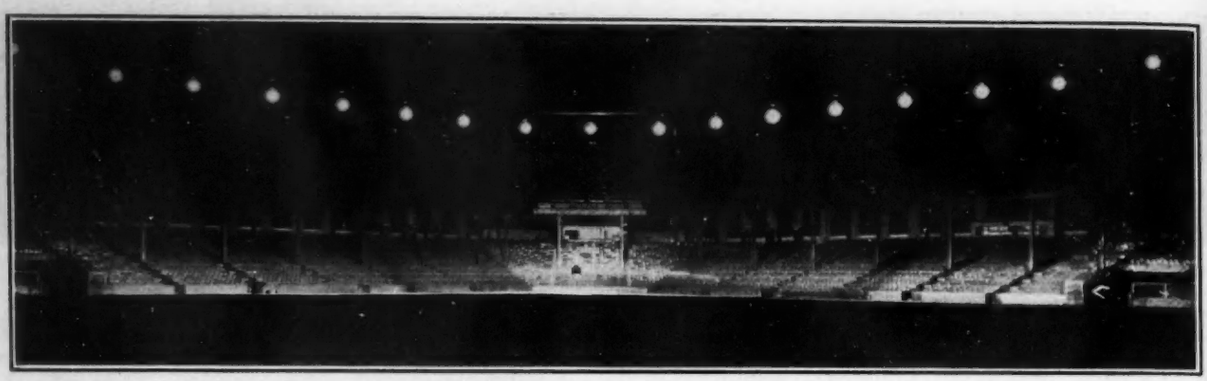


FIG. 19—ILLUMINATION OF SHIBE PARK, PHILADELPHIA
The Photograph Was Taken by the Light from a Floodlight of the Type Shown in FIG. 18. The Illumination from These Smaller Fresnel Floodlights Is Similar to That of the Large B. B. T. Floodlights Except That It Is Far Less Intense and, of Necessity, the Vertical Divergence Is Greater

speed of rotation of the searchlight at the instant the beam crosses the course of the airway. For mechanical reasons this is not as simple as it sounds, and attempts to accomplish this result with modifications of the present rotating mechanism such as cam actions or skipping gear-teeth have not been successful.

Two units with mechanisms designed by the B. B. T. Corporation in Philadelphia to accomplish this result were experimentally installed by National Air Transport on its route and have been discussed so often that I mention them despite some misgivings as to talking of a device not yet proved to be entirely successful. These searchlights, instead of being rotated constantly in one direction were arranged so that, by a simple mechanical adjustment, they were rotated from one-half

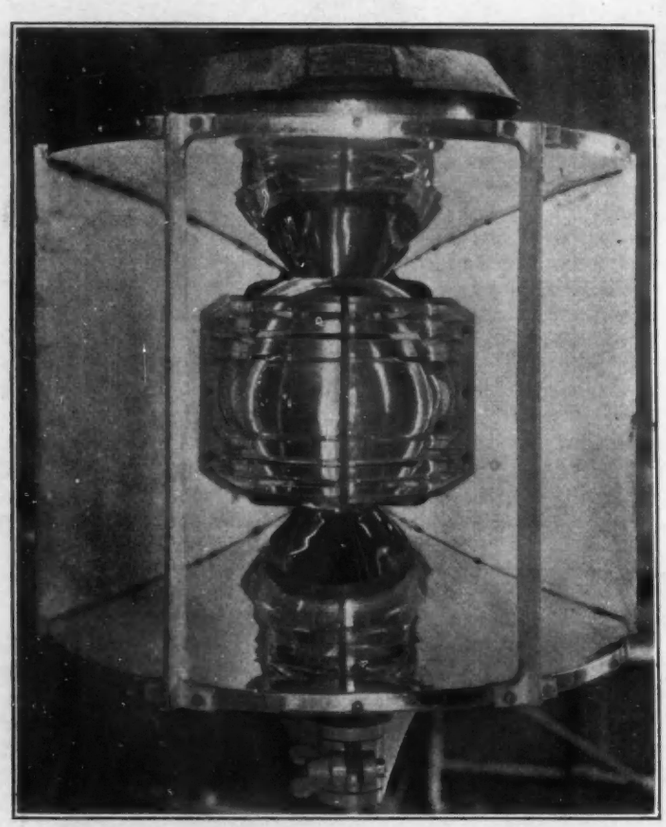


FIG. 18—NEW TYPE OF SMALL 180-DEG. B. B. T. FLOODLIGHT
It Has a Cut-Glass Fresnel Lens about 7 In. High and of 7-In. Diameter and a Spherical Mirror, Supplemented by Two 180-Deg. Circular Parabolic-Mirrors Above and Below the Lens Which Add Somewhat to the Efficiency by Utilizing Some Light from the Source That Otherwise Would Be Wasted. The Light-Source Consists of a 1000-Watt Ordinary Mazda-Lamp, a 1000-Watt Stereopticon Lamp or a 900-Watt 30-Volt Lamp, Depending upon the Specific Purpose for which It Is To Be Used. This Unit Is Also Produced with a 90-Deg. Horizontal-Divergence

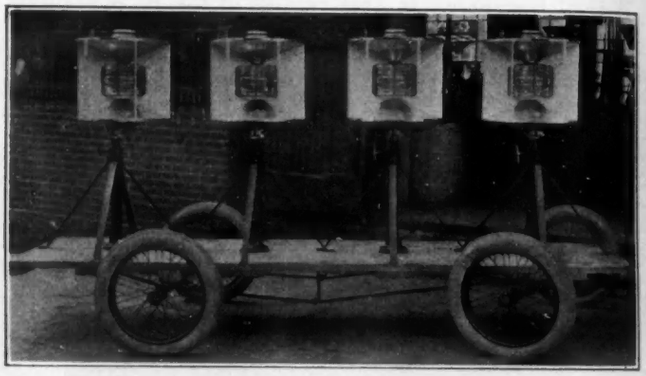


FIG. 20—PORTABLE FLOODLIGHTS
The Illustration Shows Four of the Small Floodlights Mounted on a Light Hand-Truck for Temporary Use on Large Fields Where Night Landings Are Infrequent

to three turns in one direction and then reversed. By adjusting the number of turns the beam was brought to a complete stop once on the course in each direction, and this could be done whether the light was located on a straight course or at a turn. As the motion is harmonic, the acceleration of the heavy searchlight is not too great for practical purposes. Somewhat unexpected features of this system are that the signal given to a pilot off the course is different from that given a pilot on the course and that, by adjustment of the number of turns, signals of different combinations of dots and dashes can be produced without permanent changes in the mechanism. These are obvious advantages. After a 60-day trial in service, these experimental units are undergoing minor changes in construction which have been found desirable. Of the soundness of the principle I have no doubt.

AIRPLANE LIGHTING

Navigation lights, landing lights and instrument lights must be provided on an airplane. In this connection, particularly valuable work of a pioneer nature has been carried on by Lieut. D. L. Bruner of McCook Field, Dayton, Ohio. Based on his experiments, the Pioneer Instrument Co. had built and markets the wing-tip lights shown in Fig. 21. These are powerful projectors with parabolic mirrors enclosed in light, streamlined housings and located either above or below the wing-tips. Ordi-

narily one has its beam pointed at a slight angle below the horizontal, the other at a greater angle. While I am unfamiliar with the problems involved, it seems to me that it might be desirable to give one light-beam a very small divergence so as to project the beam to a greater distance and to spread the other light-beam by using a diverging lens.

Fig. 22 is a picture of a Curtiss Carrier Pigeon used by the National Air Transport. Above the lower right wing one of the two Pioneer landing-lights can be seen. The green "starboard" navigation-light is located on the tip. On top of the vertical stabilizer is a white light visible from aft of amidships only. Projecting from below the fuselage, just aft of the pilot's seat, the chutes containing the parachute flares can be seen. The flares can be released in case of a difficult emergency-landing. Most pilots consider these the most valuable bit of night-flying equipment carried.

Neon Lights

Neon gas in tubes through which an electric current is passed gives a cold, red light, when not altered by the presence of other coloring elements. As this light has the property of piercing mist and fog to a greater degree than any other, it is obvious that it should find a use for night flying. In England, neon-gas beacons are said to have been given an enthusiastic reception. As this light cannot be used as a point source, it must depend on mass for its effect and cannot be projected; this is a possible disadvantage. A neon-gas beacon has been installed on the National Air Transport route. It is reported that under good conditions it is visible 25 miles or more and that no opportunity of discovering its ability in fog has presented itself to date.

National Air Transport Route

Because it probably is typical of the airways of the immediate future, a few words about the lighting on the route of the National Air Transport, Inc., from Chicago, via Moline, Ill.; St. Joseph, Mo.; Kansas City, Mo.; Wichita, Kan.; Oklahoma City, Okla.; and Fort Worth to Dallas, Tex., may not be amiss. The ships leave both terminals in the early morning and arrive at their destinations in the evening. The route is that of the Transcontinental Air Mail from Chicago to a point near Moline. The lights installed originally by the company run from this point to a point 50 miles beyond Moline, recommence at Oklahoma City and continue to Dallas.

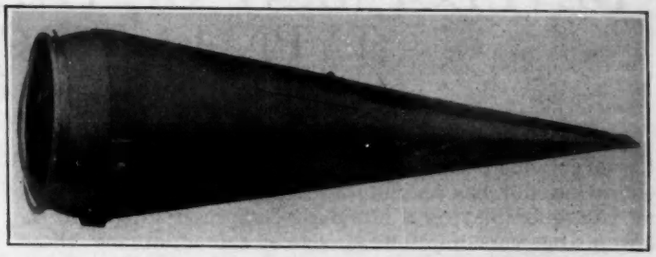


Fig. 21—Wing-Tip Landing-Light for Airplanes
This Is a Powerful Projector Having a Parabolic Mirror Enclosed in a Light Streamlined Housing and Located Either Above or Below the Wing-Tip

Rotating beacons are installed at Moline, a point 50 miles distant; at Oklahoma City; at Fort Worth; and at Dallas. At each of these four cities B. B. T. small 180-deg. floodlights are in use, and simple boundary lights. Along the route at varying intervals are American Gas Accumulator Co. 300-mm. (11.81-in.) gas flashing-beacons of the latest type, each marking the same geographical corner of a possible emergency landing-field.

Conclusions

Under the Air Commerce Act of 1926 the Department of Commerce assumes direction of the airways, including the preparation and maintenance of lighted airways. This includes emergency landing-fields but not airports, which are the responsibility of private individuals, corporations or municipalities. All this work will be under an Assistant Secretary of Commerce for Aviation.

Many persons state that directional radio and radio beacons will displace lights for night flying. This may occur, but it does not seem probable that lights can be dispensed with entirely. Gas flashing-beacons will be used to distinguish emergency landing-fields as long as unexpected storms and engine failure remain among our problems. Rotating, wabbling, flashing, or neon-gas beacons will doubtless point out the exact location of airports for some time to come, for the benefit of the many aircraft unequipped with radio that doubtless will use the airways. Limitation and obstacle lights seem to be a fixture. Big floodlights for large terminals and small ones for other terminals will be needed for some years, as it will be some time before all airplanes will carry the improved types of landing light we may expect to see.

Fig. 22—Mounting of Landing Lights
One of the Two Landing Lights Is Shown above the Lower Right Wing of the Curtiss Carrier Pigeon Illustrated

DEVELOPMENT OF THE WRIGHT WHIRLWIND TYPE J-5 AIRCRAFT ENGINE

(*Concluded from p. 308*)

has ever equalled this record for prolonged full-throttle operation, nor has an endurance test been undertaken on an engine employing a standard compression-ratio at as low a fuel consumption as was obtained during these runs. Neither am I aware of any engine having passed a full-throttle 50-hr. test at as low a specific weight as is represented by the supercharger test of the J-5 engine.

This statement is, of course, open to the criticism that the weight of the external supercharger and the power required to drive it have been neglected. On the other hand, if the supercharger were built into the engine as an integral part of the structure, the entire induction-system could be lightened sufficiently to more than compensate for the supercharger's weight, and calculations based on other models incorporating built-in superchargers indicate that the power required to drive the supercharger would not exceed 4 hp. Moreover, by redesigning the supercharger to meet the demands of this particular engine, the temperature rise could be reduced considerably, and this reduction in temperature would tend to offset the power required for operating the supercharger.

Air-Cooling versus Water-Cooling

The question of air-cooling versus water-cooling has been discussed almost continuously since the close of the war. In the past, the advocates of air-cooling have been compelled to base their case largely upon laboratory tests and single-cylinder performance, rather than on the results of service tests of developed engines in every-day service. The air-cooled position was, therefore, more or less a defensive one. Today, the situation has changed. The air-cooled engine has arrived and is daily proving its ability in actual flying-service.

It appears to me that this meeting definitely marks the point at which the advocates of air-cooling forsake the defensive attitude and assume the offensive. Henceforth, the rôles will be reversed and, instead of the air-cooled-engine designer being asked to produce results equal to those being produced by water-cooled engines, the air-cooled engine will become the standard of comparison. The air-cooled-engine designer will no longer hold before himself the best water-cooled performance as a standard to be met. This standard has already been surpassed, and the air-cooled engine has proved its superiority in weight, durability, fuel consumption, and adaptability to every extreme of flying conditions that the airplane is called upon to face.

The attainment of this enviable position for the American air-cooled aircraft-engine has been the result of a long and arduous series of developments, with which relatively few engineers have been identified. In the early days, Mr. Lawrance worked practically alone. A re-reading of the discussions pertaining to air-cooled engines published by the Society during 1921 and 1922 seem to indicate that a majority of the aeronautical engineering profession were expending a vast amount of ingenuity in thinking up new arguments against air-cooled engine development. Had an equal amount of ingenuity been devoted to the solution of the problem, progress would doubtless have been more rapid. At a later stage, much of value was contributed by S. D. Heron and G. J. Mead. The entire development program has been made possible only through the far-sighted and vigorous support of Commanders B. G. Leighton and E. E. Wilson of the United States Navy, while the extensive single-cylinder research conducted by the engineering division of the Army Air Service has been of the utmost value.

The phase has now been reached when we may expect much greater activity in this field, as several large companies having excellent facilities for research and development work are interesting themselves in the problem. The future will undoubtedly see much more rapid progress than has been made in the past. I hesitate to predict the status of the air-cooled engine 3 years from today but have no hesitation whatever in predicting that the next 3 years will see its development advancing with the utmost rapidity, as every indication points to the conclusion that there is still room for great improvement in all respects, including specific weight, power output per cubic inch, cooling capacity, durability, and facility of production.

FARM EQUIPMENT SALES

THE Department of Commerce announces that, according to data collected at the annual canvass of manufacturers of farm equipment, the value of such equipment made in 1925 amounted to $383,736,736, an increase of 18.7 per cent as compared with $323,367,127 in 1924, and 5.2 per cent over $364,854,100 in 1923.

Production values for the more important classes of farm equipment for 1925 are as follows: Farm tractors and traction engines, $120,558,518; harvesting machinery, not including haying machinery, $28,418,503; machines for preparing crops for market or use such as threshers, ensilage cutters, corn huskers, corn shellers, hay presses, feed grinders, and the like, $27,696,672; plows and listers, $23,644,833; cultivators and weeders, $17,539,172; and haying machinery, $15,457,022.

Sales of farm equipment by manufacturers for domestic use in 1925 aggregated $332,845,204, against $277,924,547 in 1924; and sales for export in 1925 amounted to $64,934,212, against $51,988,372 in 1924. The total of the domestic and export sales is not identical with the value of farm equipment manufactured, for the reason that a part of the production of 1924 was sold in 1925, and a part of the production of 1925 was not sold until 1926.

The number of farm tractors and traction engines built in the United States decreased from 135,210 in 1923 to 119,626 in 1924 but increased to 167,640 in 1925. Grain binders show a decrease in production from 55,731 in 1924 to 42,405 in 1925, together with an increase in sales from 48,323 in the earlier to 61,062 in the later year. Similarly a decrease from 126,448 in 1924 to 112,299 in 1925 in the number of mowers manufactured was accompanied by an increase from 112,462 to 118,100 in the number sold; and a decrease from 537,595 in 1924 to 516,408 in 1925 in the production of moldboard plows of all types was accompanied by an increase from 558,074 to 577,900 in the sales of such plows.

Pronounced increases have been recorded from year to year since 1922 in the production of corn binders, milking-machine units and windmills.—*Wall Street Journal.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between July 10, and Aug. 10, 1926. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

ANDERSON, ARTHUR W. (A) experimental engineer, Borg & Beck Co., *Chicago;* (mail) 6213 Greenwood Avenue.

BAKER, HARRY C. (M) engineer, Chapel Road and Baltimore & Ohio Railroad, Dayton, Ohio; (mail) 80 South Main Street, *West Alexandria, Ohio.*

BARGE, WILLIAM FRED (J) tool designer, Lycoming Mfg. Co., *Williamsport, Pa.;* (mail) 1211 West Fourth Street.

BEHN, CARL F., JR. (A) sales engineer, Robert Bosch Magneto Co., 1122 South Michigan Avenue, *Chicago.*

BRITTEN, E. F., JR., (A) vice-president, Monroe Calculating Machine Co., 555 Mitchell Street, *Orange, N. J.*

BROWN, RISDON D. (A) experimental garage foreman, Oakland Motor Car Co., *Pontiac, Mich.;* (mail) 60 Edison Street.

BUTLER, ROBERT W. (J) engineer, Robert W. A. Brewer, Ridley Park, Pa.; (mail) 162 West Sharpnack Street, *Germantown, Philadelphia.*

CEADER, JOSEPH D. (M) manufacturing engineer in incandescent lamp department, General Electric Co., Nela Park, *East Cleveland, Ohio.*

CHARLES, WILLIAM O. (A) service manager, Olds Motor Works, Lansing, Mich., (mail) 1308 Lincoln Street, *Denver.*

COREY, R. L. (A) Chicago district manager, National Gauge & Equipment Co., La Crosse, Wis.; (mail) 820 Tower Court, *Chicago.*

COWELL, F. R. (F M) chief designer, Kirkstall Forge, Ltd., Leeds, England; (mail) Mount Royd, *Horsforth near Leeds, England.*

DAILY, G. M. (A) car contract and educational representative, Manley Mfg. Co., York, Pa.; (mail) 4074 Humphrey Street, *Detroit.*

DICKEY, RALPH L. (A) president, New York Wire & Spring Co., Hoboken, N. J.; (mail) 21 High Street, *Glen Ridge, N. J.*

DUFFY, JAMES T., JR. (M) general superintendent, Steel Products Co., *Detroit;* (mail) 1346 Kensington Road.

ECHLIN, E. C. (A) factory superintendent and treasurer, Echlin & Echlin, Inc., *San Francisco;* (mail) 799 Golden Gate Avenue.

FATTLER, A. H. (F M) mechanical engineer and superintendent of manufacture, Benz Automobile Co., Mannheim, Germany; (mail) 8 Wilhelmstrasse, *Mannheim-Feudenheim, Germany.*

FREDERICKSON, OTTO A. (A) general superintendent, Wiremold Co., 252 Asylum Street, *Hartford, Conn.*

GROGAN, LEO V. (A) assistant sales manager, Studebaker Corporation of America, *South Bend, Ind.;* (mail) 401 West La Salle Street.

HARTZELL, R. S. (A) special representative in manufacturers sales department, C. O. Spring & Bumper Co. of Illinois, 1455 West 38th Street, *Chicago.*

HASSIG, EDWARD (M) chief engineer, Hannum Mfg. Co., *Milwaukee;* (mail) 247½ 14th Street.

HEY, ROY ELKINGTON (J) detailer layout draftsman in general automobile chassis works, Pierce-Arrow Motor Car Co., *Buffalo;* (mail) 1420 Kenmore Avenue.

HOEHN, RUDOLPH W. (A) special service representative, White Motor Co., *Cleveland;* (mail) 1471 East 118th Street.

HUISH, E. H. (A) assistant manager, Ford Motor Co., Detroit; (mail) 450 Pennsylvania Avenue, Northwest, *City of Washington.*

HYLTON, C. F. (M) technical assistant to sales department, Karrier Motors, Ltd., Huddersfield, York, England; (mail) Engineer's Club, Coventry Street, *London W., England.*

JEACOCK, THOMAS W. H. (A) president, Buffalo Bronze Die Cast Corporation, 100 Arthur Street, *Buffalo.*

JOHNSTON, JAMES A. (M) mechanical engineer, Commerce Motor Co., *Ypsilanti, Mich.*

KELECOM, PAUL E. (F M) vice-president and chief engineer, Societe Anonyme du Servo-Frein Dewandre, *Liege, Belgium;* (mail) 38 Rue Louvrese.

KING, HAROLD MCCULLOUGH (J) laboratory assistant, White Motor Co., 842 East 79th Street, *Cleveland.*

KORSHIN, MATTHEW R. (A) special representative, Whitney Mfg. Co., *Hartford, Conn.*

KUMPERA, TENY (F M) assistant chief engineer, Gnome & Rhone Aircraft Motors Mfg. Corporation, 18 Avenue Bugeaud, *Paris XVI, France.*

LEWIS, HOWARD B. (M) experimental engineer, Hughes Tool Co., *Houston, Tex.*

MACFEIGGAN, JOHN J. (A) service representative, Eclipse Machine Co., Elmira, N. Y.; (mail) 1342 Book Building, *Detroit.*

MAUK, BENJAMIN FRANKLIN (A) superintendent, Fort Dearborn Mfg. Co., Rock Falls, Ill.; (mail) 610 West Fifth Street, *Sterling, Ill.*

MELOON, NATHANIEL W. (M) vice-president and general manager, Buffalo Bronze Die Cast Corporation, 100 Arthur Street, *Buffalo.*

MILLS, J. E. (A) commissioner, department of purchases and supplies, City of Detroit, *Detroit;* (mail) 2229 West Grand Boulevard.

MOHNS, LESLIE (J) draftsman, Rockford Drilling Machine Co., *Rockford, Ill.;* (mail) 517 Oak Street.

NEELANS, HAROLD, G. (J) engineer in experimental laboratory, Dodge Bros., Inc., *Detroit;* (mail) 5087 Ivanhoe Avenue.

NEELY, WILLIAM H. (M) director of engineering, Graham Bros., *Detroit.*

NEWELL, GEORGE A., JR. (A) branch manager, Fruehauf Trailer Co., Detroit; (mail) 437 Fourth Street, *San Francisco.*

NICHOLS, ALFRED LESLIE (A) automotive engineer, Vacuum Oil Co., Proprietary Ltd., Melbourne, Australia; (mail) Moonthalie, White Horse Road, *Mont. Albert, Melbourne, Australia.*

PARKIN, J. H. (M) assistant professor in mechanical engineering, University of Toronto, Mechanical Building, *Toronto 5, Ont., Canada.*

PAUL, F. O. (M) service manager in automotive car division, J. G. Brill Co., Philadelphia; (mail) Beverly Apartments, *East Lansdowne, Pa.*

PFISTER, CHARLES F. (M) 86 Baldwin Avenue, *Baldwin, N. Y.*

RAFTERY, BASIL F. (A) assistant foreman, Checker Cab Co., *San Francisco;* (mail) 161-B Prospect Avenue.

RAGALIE, JOSEPH M. (A) president, Ragalie Bros., 3939 West Fifth Avenue, *Chicago.*

RAMSEY, J. A. (A) president, Ramsey Accessory Mfg. Corporation, 1107 North 15th Street, *St. Louis.*

RAMSEY, PAUL (J) draftsman, Olds Motor Works, *Lansing, Mich.;* (mail) 736 West Allegan Street.

REID, EARL (M) development engineer, Manhattan Rubber Mfg. Co., Passaic, N. J.; (mail) 122 South Michigan Avenue., *Chicago.*

ROBINSON, GEORGE H. (M) assistant chief engineer, Durant Motors, Inc., Newark Avenue, *Elizabeth, N. J.*

RUFF, ALBERT E. (J) draftsman, International Motor Co., Anable Avenue and Moore Street, *Long Island City, N. Y.*

SCHUETZ, THOMAS J. (M) chief engineer, Braden Steel & Winch Co., *Tulsa, Okla.;* (mail) 3 North Madison Street.

SOEHNER, HOWARD C. (J) experimental engineer, Brooks Steam Motors, Ltd., *Stratford, Ont., Canada;* (mail) 180 Cobourg Street.

TAUB, LOUIS (J) Chrysler Corporation, *Highland Park, Mich.*

TEMPLE, HERBERT R. (A) shop superintendent, H. J. Ruddle Co., 770 East Ninth Street, *Los Angeles.*

TORON, ERNST W. (F M) chief engineer, Dr. L. Michaelis Ingenieurburo, Berlin W. 62, Germany; (mail) Knesebeckstrasse 48-49, *Berlin W. 15, Germany.*

TOWLE, H. LEDYARD (A) director of Duco color advisory service, E. I. du Pont de Nemours & Co., 285 Madison Avenue, *New York City.*

TYLER, LEE L. (A) general shop superintendent, Frisbie Motor Co., *Middletown, Conn.;* (mail) 30 Johnson Street.

VISCHER, ALFRED (F M) constructive engineer and manager of plant, Daimler Motoren Gesellschaft, *Stuttgart-Unterturkheim, Germany.*

WARD, GEORGE LEOPOLD (M) research engineer, Standard Oil Co. of New Jersey, Elizabeth, N. J.; (mail) 250 East Third Avenue, *Roselle, N. J.*

WEED, ROBERT F. (A) sales manager of automotive division, American Cable Co., Inc., 929 Connecticut Avenue, *Bridgeport, Conn.*

WESTBY STANLEY (F M) draftsman, Morris Motors, Ltd., Cowley, Oxford, England; (mail) 67 East Avenue, Cowley Road, *Oxford, England.*

YOUNG, FENTON R. (J) levelizer sales department, American Chain Co., Bridgeport, Conn.; (mail) 1112 Broadbridge Avenue, *Stratford, Conn.*

Applicants *for* Membership

The applications for membership received between July 15 and Aug. 14, 1926, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ARSENAULT, LOUIS MAURICE, president and general manager, Derby Motor Cars, Ltd., *Saskatoon, Sask., Canada.*

BAK, JOSEPH V., foreman and body designer, Studebaker Corporation of America, *Detroit.*

BARNETSON, WILLIAM W., superintendent, American La France Fire Engine Co., *Toronto, Ont., Canada.*

BELLANCA, GIUSEPPE M., consulting aeronautical engineer, Wright Aeronautical Corporation, *Paterson, N. J.*

BITTLES, WILLIAM J., general manager, Pie Bakeries of America, Inc., *Newark, N. J.*

CHARLES, J. PAUL, resident engineer, General Motors Corporation, General Motors Proving Ground, *Milford, Mich.*

COLE, FRANCIS GANDY, distributor for Protectomotor air filters, Staynew Filter Corporation, *Rochester, N. Y.*

COLVIN, CHARLES H., president and general manager, Pioneer Instrument Co., Inc., *Brooklyn, N. Y.*

CONE, H. I., vice-president and treasurer, Daniel Guggenheim Fund for the Promotion of Aeronautics, *New York City.*

COOK, ALBERT CASE, vice-president, Warner & Swasey Co., *Cleveland.*

DAY, ALVIN N., Pacific coast manager, Overman Cushion Tire Co., *New York City.*

HARGER, MARSHALL C., student apprentice, Rolls-Royce of America, Inc., *Springfield, Mass.*

HAVLIN, JOHN F., appraiser and adjuster, *Boston.*

HEINZ, ARTHUR A., designer, General Motors Truck Co., *Pontiac, Mich.*

HUBER, HENRY, draftsman, Yellow Sleeve-Valve Engine Works, *East Moline, Ill.*

HURTH, FRITZ, mechanical engineer, Maschinen & Zahnradfabrik Carl Hurth, *Muenchen, Germany.*

HUTCHENS, L. E., manager, lubricating department, Empire Refineries, Inc., *Tulsa, Okla.*, Cities Service Oil Co., Tulsa, Okla. and St. Paul, Minn.

LAMBERT, KENNETH BENNETT, telephone engineer, Bell Telephone Laboratories, Inc., *New York City.*

LEDERER, JEROME, aeronautical engineer, Air Mail Service, *Maywood, Ill.*

LIND WILLIAM, General Motors Export Co., *New York City.*

MCCUEN, CHARLES L., experimental engineer, Rickenbacker Motor Co., *Detroit.*

MANKOFF, FRED J., vice-president and general manager, Motor Equipment Co., *Wichita, Kan.*

MORELLO, JOAQUIN D., service engineer, General Motors Export Co., *New York City.*

MORSE, WILLIAM I., experimental machine foreman, General Motors Truck Co., *Pontiac, Mich.*

OFSTIE, ARTHUR O., motorcoach and automotive lubricating sales engineer, Standard Oil Co. of Indiana, *Minneapolis.*

PERDUE, JOHN J., service manager, Gotfredson Corporation, Ltd., *Walkerville, Ont., Canada.*

REED, W. S., mechanic, Nored Service Station, *Fort Worth, Tex.*

RINEHART, LESTER, superintendent of machine shop, Hale Fire Pump Co., *Conshohocken, Pa.*

ROBBINS, ARCHIE W., sales representative, Bearings Co. of America, *Lancaster, Pa.*

ROBERTSON, WILLIAM B., president, Robertson Aircraft Corporation, *Anglum, Mo.*

STEWART, R. M., service representative, General Motors of Canada, *Oshawa, Ont., Canada.*

STRATTON, ROBERT W., mechanic, State of Idaho, *Boise, Idaho.*

TAYLOR, THOMAS D., metallurgist, Bliss & Laughlin, Inc., *Harvey, Ill.*

THORNTON, O. M., branch manager, Titeflex Metal Hose Co., *Newark, N. J.*

TILLBERG, C. E., shop superintendent, Twin City Motor Bus Co., *St. Paul, Minn.*

WAWRZINIOK, OTTO C. E. P., graduate engineer and appointed professor, Technical University, *Dresden, Germany.*

WEEKS, ERNEST GEORGE, automobile trouble shooter, Troy Motor Sales Co., *Los Angeles.*

YAWN, HENRY CLAY, JR., manager of dimension stock factory, Goodyear Yellow Pine Co., *Picayune, Miss.*

YOUNG, MELVIN GORDON, 106 Walden Street, *Cambridge B., Mass.*